IMPROVEMENT

IN

BUILDING CONSTRUCTION

INCLUDING A

TREATISE ON PORTLAND CEMENT CONCRETE; ALSO PORTLAND CEMENT CONCRETE COMBINED WITH IRON OR STEEL AS A BUILDING MATERIAL WHEN USED IN ASSOCIATION FOR THE SUPPORT

OF

Walls, Floors, Sidewalks, forming Roofs to Vaults, Foundations, Etc.

DISPENSING WITH THE USUAL COSTLY IRON OR STEEL BEAMS, THUS SAVING TWO-THIRDS THEIR EXPENSE

ALSO

TABLES

OF SAFE-BEARING LOADS OF HOLLOW CAST-IRON COLUMNS, PILLARS, ETC., ETC.

BY

P. H. JACKSON

SAN FRANCISCO
THE BANCROFT COMPANY
1890

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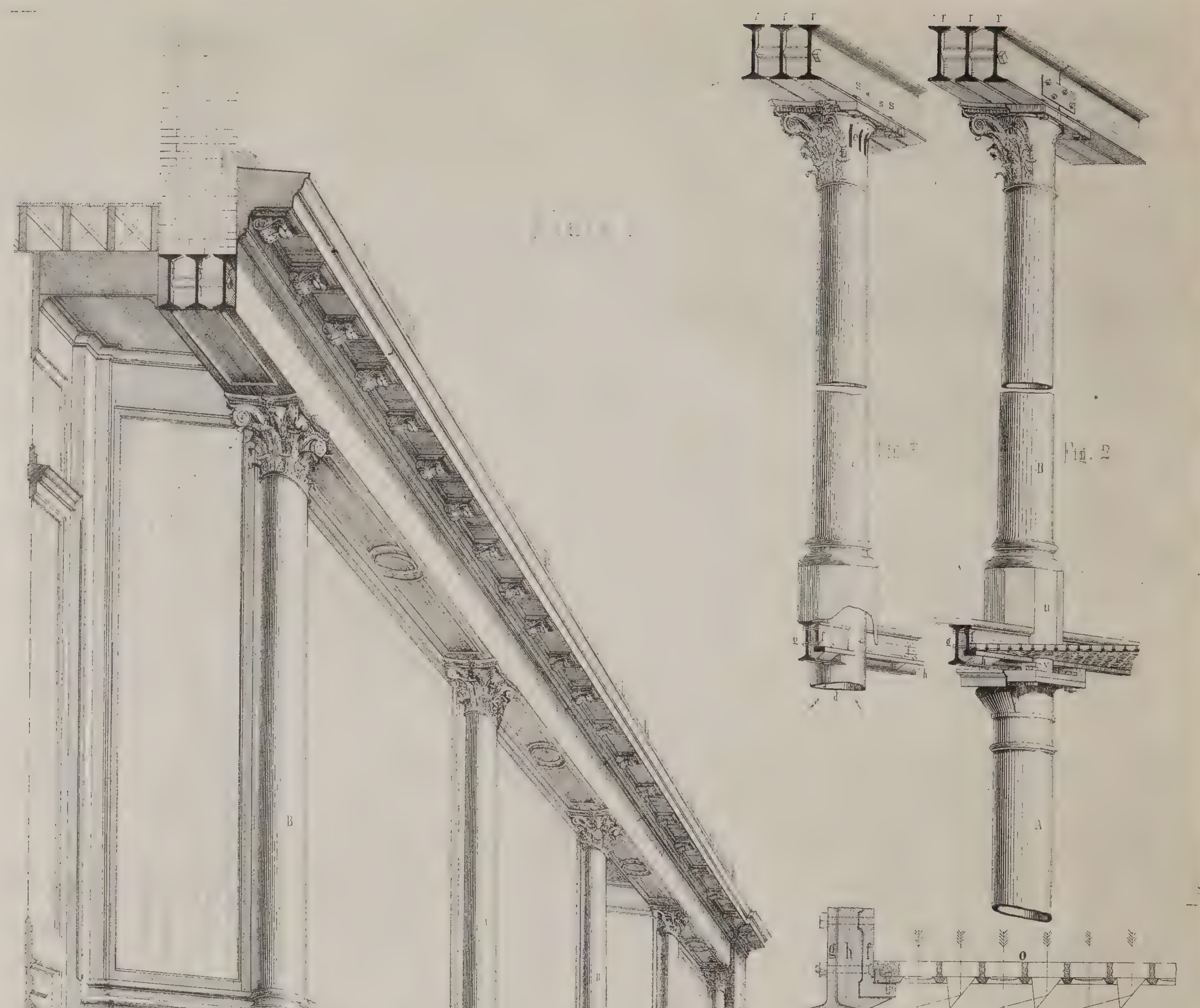


JACKSON'S PATENT BASEMENT CONSTRUCTION

Where business property is valuable, the basement should be a bright, well-ventilated, cheerful, continuous apartment, of co-ordinate value for business purposes with the other parts of the building. The damp, dark basements of most of our business structures are caused by faulty construction, the daylight which passes profusely through the sidewalk lights (when the latter are in sufficient quantity) is prevented from lighting towards the rear by the large intervening basement piers, one under each of the first story columns above; these piers not only shut out fully one-half the light, but increase the dampness by its exclusion, and also serve to divide the basement proper from that portion under the sidewalk, instead of forming one large basement room extending from rear wall to front wall under the curbstone.

Railway Engineers construct bridges of 500 feet span, or one pier resting on foundation to every 500 feet, spanning turbulent streams, to sustain moving railway trains at lightning speed. In building construction, the load being at rest, the spans may be 25 feet where such beneficial results are to be attained by changing the construction from the present damp, dark apartments to light and cheerful places, suitable for the sale of fine goods at retail, for saloons and similar purposes.

Attempts have been made to so construct that the light may pass unobstructed to the rear of the basement, by leaving out some of the basement piers and using an iron beam across the top on a line with the bottom of the beam riser, to support the weight of the first story. This beam of necessity extends down its depth and shuts out the light like a curtain at the most valuable part; this obstruction to light is equal to that described for the basement piers.

It is folly to expect to light a basement by a plentiful supply of lights in the sidewalk, with the entrance to the basement from the space under the sidewalk partially closed by the usual large basement piers, which in many cases are equal to a semi-dividing wall.

The slanting rays of light from the different angles of the sun during the day are largely lost in shining back by shade on the sides of deep basement piers, therefore, it is not only the width of the pier, but the depth also that obstructs light from the sidewalk lights to the basement proper under the building.

Where the property is valuable there is no part of the building that will make so profitable return for the expenditure as in making the basement a light, dry, well-ventilated and cheerful apartment.

The new *Chronicle* building now in process of erection in San Francisco is to have sidewalk lights which are to extend 9 feet from the building, and the length of both fronts. The proprietor realizes the value of light in the basement.

We have other means of ventilation than those shown in the illustration. We may mention, that this improvement is applicable to any design of the architect.

Figure 1 merely shows every other basement post omitted, but the omission may be double that number or even more.

The iron basement posts are made of the smallest possible size for strength so as to cause the least obstruction to light and room. **An iron post will safely sustain fully 30 times the load of a brick pier of equal size.**

The suspended 1st story columns (c) serve as flues to ventilate basement (see detail in Figure 3). The top of the column is bolted to the girder above, and its base rests upon beam *g* and riser *f*. The iron beam riser (*f*) is attached by heavy iron brackets (*h*) to the wrought-iron beam at its back (*g*), their under surfaces project but a trifle below the bottom of sidewalk lights (see Fig. 1) thereby permitting their rays to shine back from the patent refracting lenses towards the rear of the basement. Detailed figure 4 shows the patent refracting lenses to be used in the sidewalk lights in Figure 1, the arrows indicate the direction of the rays. **Also Hyatt's Patent Reflectors to direct the light from Sidewalk Lights in any direction.**

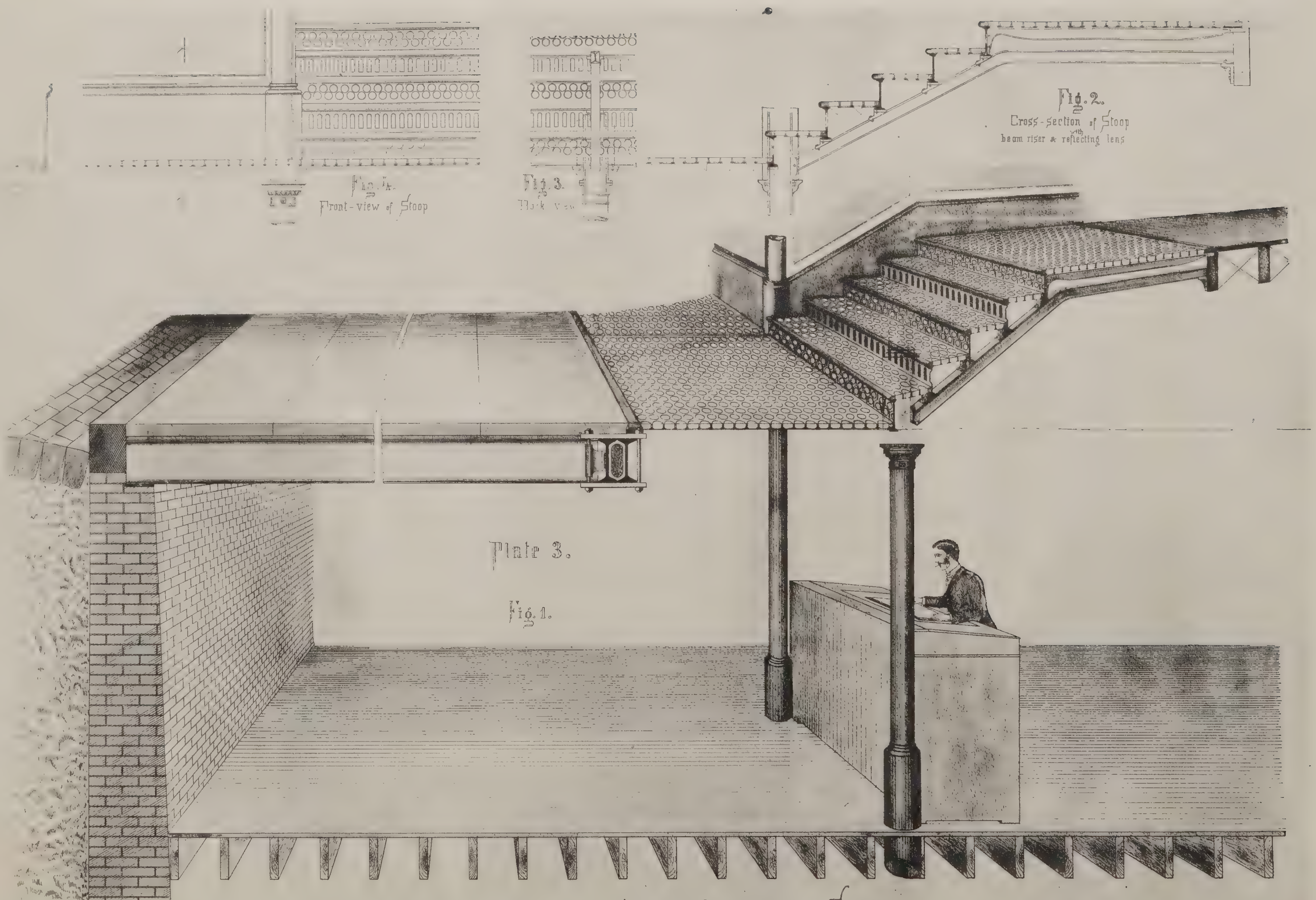
The two beams (*k*) form a girder supporting the outer edge of sidewalk lights, and inner edge of sidewalk, each of them equally employed in the support of the end of the tail beam (*m*) which is not the case with any other kind of this construction. The beams (*m*) may be substituted by Hyatt's metallic ties as shown in plate 2, saving about ⅔ their cost.

Our illuminating tiles are made of stone and glass. No iron is shown on the surface, so that the entire top is of artificial stone with the intervening glass lenses. These tiles have no iron knobs to collect dirt and obstruct light to basement.

When iron frames are used bordering the illuminating tiles, in addition to the objectionable iron surface before described, about 17 per cent. less of glass is inserted to a width of 4 feet out, and other widths in proportion, giving that amount of light less to the basement to what it would be if our improved construction of all stone and glass on surface was used.

We manufacture Patent Sidewalk doors and frames that do not leak to basement, the only kind made, also, **other improvements.** Correspondence solicited.

P. H. JACKSON & CO., 228 & 230 First Street, San Francisco, Cal.



This illustrates the value for light & space of a Patent Illuminating Stoop

JACKSON'S PATENT ILLUMINATING STONE STOOP

While with **Our Patent Illuminating Stone Stoop the Basement and space under the sidewalk are united in one large room,** extending from the rear wall out to the front wall under the curbstone, as shown in Fig, 1, Plate 3, brilliantly lighting the basement proper and basement extension under the sidewalk, **a Stone Stoop** not only excludes all light from **without** to the basement, but the requirements for its support separate the basement from the space under the sidewalk, and probably leave room for a closet under it for ash barrels or as a receptacle for rubbish.

Book-keepers, at their desks under our stoop, usually have a movable window shade to keep out the glare of the sun.

The surface of our stoop and sidewalk are all of stone and glass—no iron, excepting the illuminating risers, each of which is a combined beam for the support of the tread, a riser, and nosing protector to prevent chipping the outer edge of the stone step. The usual unsightly iron stringers used for the support of iron stoops are not needed, leaving the space they would occupy for light. The top platform of stoop may be inlaid between the glass with encaustic tiling in various colors, as in the vestibule floors of the Flood building.

Referring to Figure 1, Plate 3, the dark strip shown between the sidewalk lights and sidewalk should not appear but be of the same color as the sidewalk, being part of it.

In cross section, Fig. 2, patent refracting lens are shown which emit light from the side of the semi prism, and throw it back to the rear. To the left of Fig. 4 is a section through x—y of an iron panel under store window (which may be open work for ventilation) the bottom of the iron panel has a flange on it, which makes it of beam strength for the purpose of supporting the inner edge of sidewalk light.

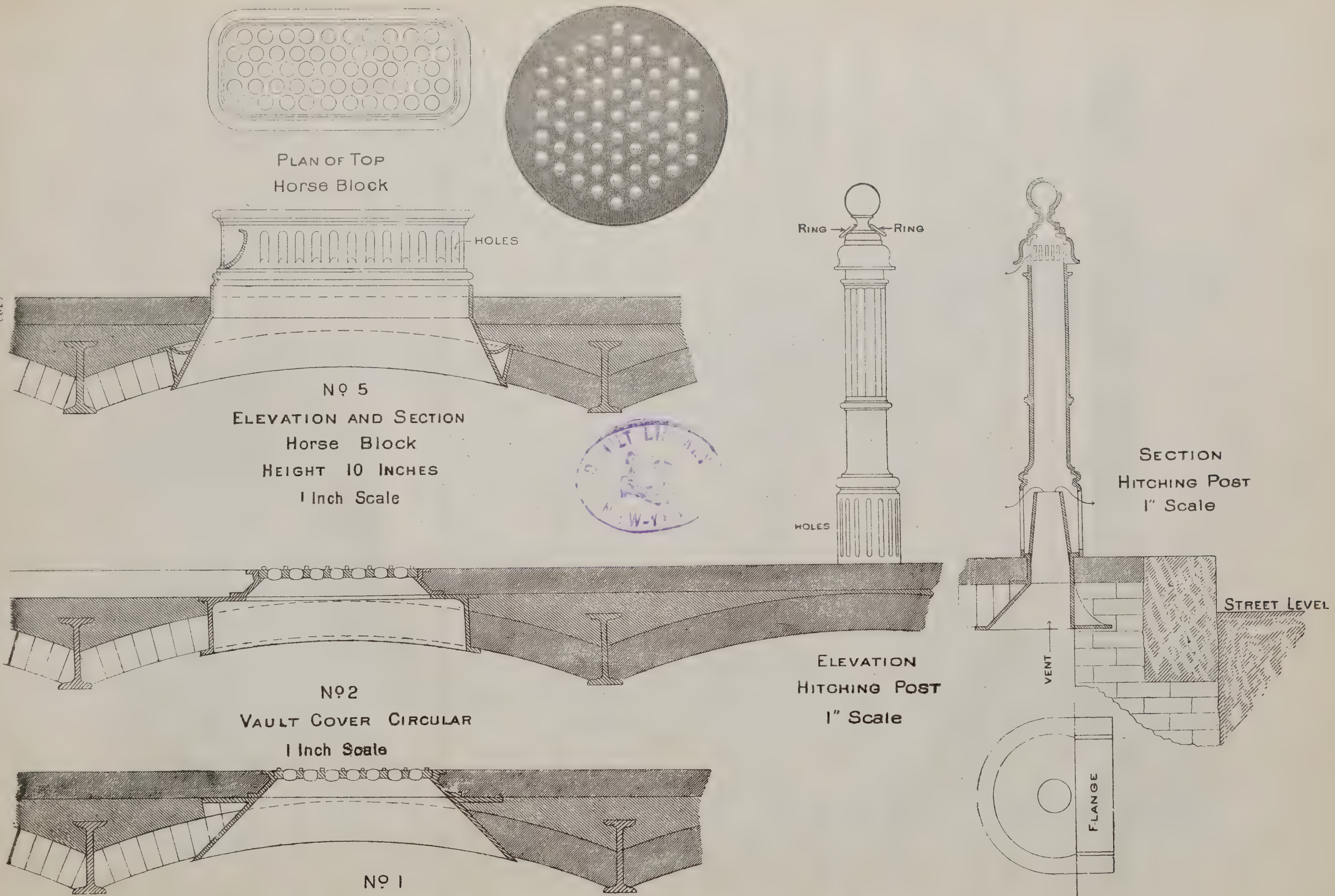
A basement bears the same relation to light as the top story of the building, with this difference: the top story receives daylight direct through the skylight while the basement must receive light **at the top from one end**, and the mere projecture down of a small cross-beam at this most important part shuts off a good deal of light, particularly when the sun is at an angle, and a large cross-beam is like a curtain and light comes down as through a well-hole and passes below it to the side to basement. **It will be observed in all our constructions for light there is the least possible projecture below the bottom surface of the illuminating tiles that the light may pass direct to the rear.** When we complete this work ourselves it is as well done as if for the parlors of the building, and no possible leaks.

On the next page is shown a section and elevation of our ventilating hitching-post, which is built in the arch and sidewalk near the curb, and serves the purpose of a flue to ventilate the basement.

No. 5 is an elevation of a ventilating carriage block or step, which is built in near the curb as described for hitching-post, the top illuminating tile above it is of stone and glass. We have other modes of ventilation.

No. 1 is a section of an illuminating vault cover, usually two feet in diameter, of iron and glass or stone and glass, with a flaring ring the thickness of sidewalk, and below it is a flaring flange about the thickness of the arch in which it is built when the arch is made, this permits the spread of light from the vault cover over a large area in the basement, thereby fully double the light is obtained in the basement from the illuminating vault cover to what there would be without it.

The round iron vault light shown we make of sizes varying from 14 inches to 36 inches in diameter, with a flaring ring for 18-inch and larger covers. We also make them of stone and glass, usually 24 inches in diameter, with flaring ring as shown in No. 1 section, and also the flaring flange before described when called for.



Plan of Top
Horse Block

No. 5
Elevation and Section
Horse Block
Height 10 Inches
1 Inch Scale

Elevation
Hitching Post
1" Scale

Section
Hitching Post
1" Scale

No. 2
Vault Cover Circular
1 Inch Scale

No. 1
Vault Cover Circular
1 Inch Scale

Plan - Looking up

THE FOLLOWING ROUND-ABOUT AND EXPENSIVE WAY OF MAKING ROOFS OF VAULTS, WITH ARTIFICIAL STONE SIDEWALK ABOVE, IS AS FOLLOWS:

First, upon iron or steel beams brick arches are built, with their top surfaces made flat, and upon them is spread a layer of sand; upon the sand is formed the artificial stone sidewalk. The sand is a separator to prevent the lower surface of sidewalk from adhering to the top of the arches, if they stick together the artificial stone is not free to contract during shrinkage, when solidifying and hardening from the plastic state.

If the artificial stone sidewalk is made in large slabs, notwithstanding the layer of sand to slide over, it will also crack, as it has not the strength due to its thinness, to draw the extremities of the slab towards middle part, during solidification and early induration. The contraction subjects it to severe tensile strain and its adhesiveness in places is destroyed.

By this construction the iron or steel beams sustain the entire load, that is, of the arches, sidewalk, and imposed loads. The arches form the roof to vault and are required to sustain the load of sidewalk and imposed loads. The sidewalk is an idle load, depending on the arches and beams for support; its function is a suitable wearing surface.

CONTRASTED IMPROVEMENT IN THE MANNER OF PLATE 2

First—The iron or steel beams are dispensed with, saving two-thirds their cost.

Second—The arch and sidewalk are one piece in thickness, the two united in the strength of the arch, and are two-thirds self-sustaining.

Third—The arch and sidewalk being of less material, a saving is obtained of what would be a distinct sidewalk and the difference in thickness is, of course, added to the height of the apartment beneath.

Fourth—It never cracks, as the material in sidewalk and arches is employed only ***at its greatest strength in resisting compression,*** its comparative great weakness in resisting extension is not called into play, as a body to separate must be subjected to tensile strain, compression, being directly the reverse.

Its strength and durability is fully equal to the common method.

Referring to Plate 2. The arch and sidewalk are one in thickness, incorporating the two in the strength of the arch, and are made in sections. The combined arch and sidewalk being in sections, each part is free to shrink and draw towards its own center, which not only prevents cracking and separation due to shrinkage so common in artificial stone continuous arches where the arch and sidewalk are one in thickness, but the material is employed in its greatest strength without engaging its comparative feeble strength. (See quotation from General Gilmore's work further on.)

It is formed as follows: (See Plate 2.)

The two end sections that rest upon the walls, with the three middle sections which form supporting beams are first made; in the bottom of the latter, built in, are shown three of Hyatt's patent iron or steel ties. These supply the required tensile strength along the bottom or footings of the arch where the concrete is weak to resist, and they balance in strength the upper portion, the strong part of the material, so the concrete beam, properly proportioned, possesses equal resistance to compression and extension. This combination may be relied upon for strength and durability equal to that of a metallic beam. The Hyatt ties are so firmly held in the concrete bond, that they will tear asunder before loosening in the surrounding material.

These five sections are made first by setting planks on edge resting upon substantial centers, and at angles radiating to the curve of the arch. After the centers, etc., are covered with tarred paper, cloth, or equivalent material, which must cover the entire bottom to prevent the escape of moisture from the concrete, the concrete material is then filled in on the centers between the planks of the section to the depth of one and a half to two inches, according to the number of ties used, and then suitably compacted by iron rammers. The surface is then scratched and moistened and the Hyatt ties are laid on, with their surfaces completely coated with liquid Portland cement of the consistency of thick cream, and the concrete material to be well compacted between and around the ties and up to their tops, the surface is then scratched and dampened before the material for the succeeding layer is filled in. When full, and properly compacted, the surface is smoothed and finished in a manner usual in making artificial stone sidewalks.

After thirty hours, the planks are withdrawn, and the sides where the planks were plastered smooth.

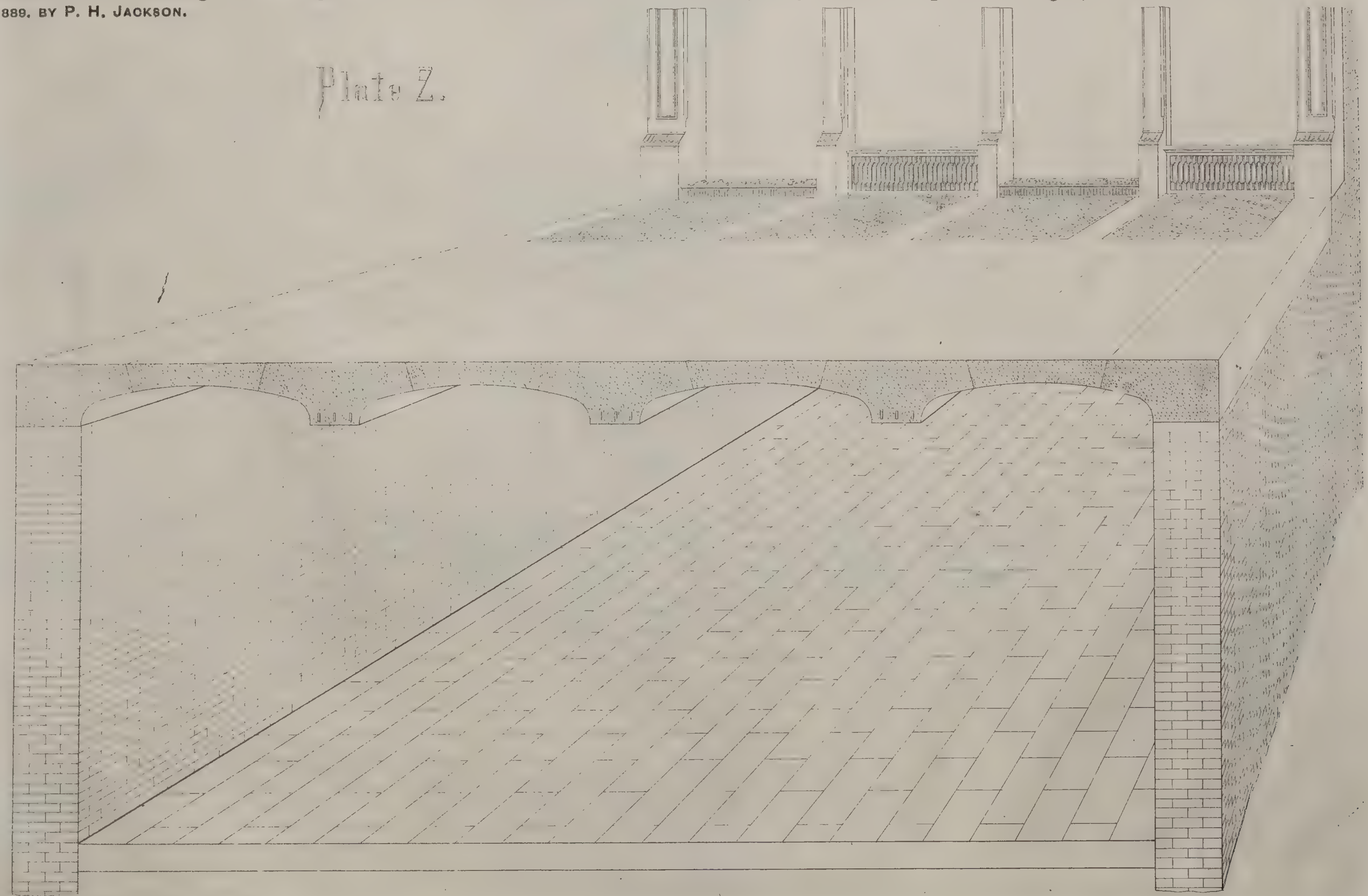
JACKSON'S PATENT SECTIONAL ARTIFICIAL STONE ARCH AND SIDEWALK combined with HYATT'S PATENT METALLIC TIES, dispensing with iron or steel beams, saving two-thirds their cost, and of equal strength.

The sidewalk and arch never crack, as the material is compressed in both direct and cross directions.

The sidewalk and arch are one piece in thickness, incorporating the two in the strength of the arch, and admits of more room in the vault beneath.

The inner ends of the supporting arches in this plate are sustained by basement piers, but they may be omitted with the advantages before explained, and the ends of the arches to be supported by an iron girder as shown in Plates 1, 3 and 5, omitting the tail beams, but using with the **iron girder the beam connections** shown in those plates, which support the ends of the concrete beam supporting arches. The illuminating stone tiles may then extend continuously the length of front between the building front and girder as shown on Plates 1, 3 and 5, or they may extend but part the length, as desired.

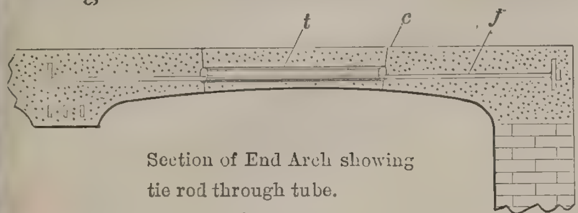
Plate Z.



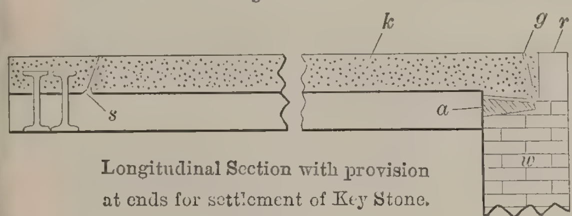
In San Francisco alone there are over 60,000 feet of combined artificial stone sidewalks and arches with metallic ties, the arches spanning the vaults beneath, mainly constructed by Mr. Ransome. The Academy of Sciences, now in course of erection, is to have fire-proof floors of concrete and metallic ties of spans about thirty feet. Messrs. Percy & Hamilton are the architects.

We sell these Metallic Ties by the pound to concrete makers and others.

To Resist the Horizontal Thrust of the End Arch, where the End rests on the Wall in Plates 2 and 6, and to allow the Keystone Section to settle, and depend on the Tapering Sides of the side Supporting Sections—It is usual to employ for this purpose iron tie rods, with one end inserted through the web of the beam or attached to its top flange, and the other end resting upon or above the wall. In Fig 1 of the accompanying illustration, which is a cross section, the tie rod (*f*) described is shown with an anchor plate on each end. As the keystone (*c*) in the figure must be independent of the rod; provide a water-tight thin tin tube, (*t*) of oblong shape, ⅝ of an inch larger the long way than the rod (*f*), and to be of the length, and with the ends of the exact shape of what the tapering sides of the keystone is to be. Press the tube above the rod as shown in the figure, and press in from the ends of tube, hard brown soap or stiff putty (the former preferred), so as to keep the tube above the rod, or it may be held up by strings when in place. The soap prevents the concrete from entering the tube. Use as little soap as possible for the purpose.



Section of End Arch showing tie rod through tube.
Fig.1.



Longitudinal Section with provision at ends for settlement of Key Stone.
Fig.2.

When the keystone is formed and dry and hard, and the centers are dropped, the soap in the tube will be crushed by the weight of the keystone which will drop as far as the rod is concerned fully half an inch. The tie rod (*f*) with end plates resists the horizontal thrust of the arch, and the keystone is independent of the rod to settle.

The Keystone Sections of Plates 2 and 6 must not rest upon any End Support, but depend entirely on the Tapering sides of the Supporting Sections—Referring to Fig 2 of the accompanying illustration at the left at (*s*) is shown a tapering separation, which permits the keystone to settle independent of the adjoining part farther to the left supported by the two girder beams. The separation to be formed in the manner described, for the tapering sides, but the taper to be of the reverse way. The division (*s*) only to extend the width of keystone. The other end of the keystone at the right, to be separated the same way, and just inside the end support. To prevent leak, cut a groove as shown at the bottom at (*s*) in the figure, to be somewhat deeper than its width, and fill in with Portland cement. Or a piece of wood of the shape to form the groove may be laid on the center at the bottom at (*s*), and the keystone formed on it, and when the centers are dropped, withdraw the wood and fill in with Portland cement.

There is another way shown at the right of figure, which letters (*a*) and (*g*) have reference; that is explained in connection with figure 6, but consider it not as practicable as the before described method.

After allowing five days for the artificial stone or concrete to set, some separating material, such as tarred paper, oth, or other equivalent is placed against the sides where the planks, set at angles, were. This has finished the five pporting sections shown in Plate 2, two of which rest upon the walls, and the three are Hyatt's concrete supporting ams; then fill in the material between them which form the keystone parts, compact in layers, etc., as before directed.

The keystone sections are of wedge or Vouissoir form and rest on the skewback sides of the supporting beams d end sections. Tie-rods with anchor plates at ends, having tin pipes on them larger than the diameter of the rods d built in the concrete, resist the horizontal thrust of the end sections and at the same time permit the keystone rts to slip down, wedge, and compress against the skewback portions.

After thirty-five or forty days have expired since finishing (not before) the centers and bottom may be dropped, ***nd then only providing a small quantity of water has been used in the concrete mixture.*** 'hen the concrete has been overdosed with water not only has its ultimate strength been impaired, but it takes much nger to solidify and harden, as described farther on.

After the centers are taken away, the keystone sections compress all the parts in a cross direction, including emselves, employing the material in its greatest strength without engaging its comparatively feeble tensile strength, king up and urging all shrinkage or shortening of the material during the process of solidification, and induration or rdening from the plastic to the solid state, rendering it impossible to crack, and remedying the general great fault of mbined sidewalks and arches, and independent sidewalks as well, of this material.

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An artificial stone or concrete body, be it a sidewalk, arch, or arch and sidewalk combined, the same as a body cast iron (in common with every material that shrinks), will occupy less space when solidified than it did in a plastic melted state, and, in this condition, if it has not the strength from its thinness compared to its length, or from regular thicknesses, to draw the mass towards the center, or the thicker parts to draw to themselves their surrounding, will separate in parts; but with the arches in sections as in Plate 2, the shrinkage is not only taken up, but great edge pressure is exerted in the direction of the contracting material.

For the material to crack it must be subjected to tensile strain beyond its capacity to resist. The compressive squeezing force employed in the Jackson process is directly the reverse of tensile strain.

The concrete beams from the nature of their employment are compressed over their length in the upper half of eir section, the greatest on top, and the keystone sections resting upon the wedging sides of the beams partake of is compressure or shortening force; therefore, the compressive force is exerted in both direct and cross directions, nploying the material in its very great strength, viz.: resistance to crushing. The patent for this construction claims e keystone parts may be made in cross sections as well, but it is found not to be necessary.

In General Gilmore's Treatise, entitled, "Coignet-Beton and other Artificial Stone," page 54, he says, "With a ixture of one volume of Portland cement to five volumes of sand, the ratio of crushing strength will generally be ***ound thirty-five times greater than its tensile strength."*** The Hyatt ties supply the deficiency. 'he immensely strong portions of the concrete material of the beam supporting sections, performs the functions of a p flange and web of an iron beam, and the requisite tensile strength to supply the thirty-five times deficiency, equiva- nt to the bottom flange of the beam, is supplied by the Hyatt ties; the whole performing the entire functions of an on beam, and its strength may be computed as that of an iron beam. The Hyatt ties (drawings of one kind are shown the following figure *a*, and in Plate 4), are held in every part over their length in the concrete bond, the raised por- ons of the ties unite and hold to the concrete in effect as the rivets unite the bottom flange of an iron beam to its web.

The thickness of the combined arch and sidewalk is about four and a half inches less than in the ordinary onstruction of the brick arch, layer of sand, and sidewalk slab, thereby not only saving material but increasing the oom from floor to ceiling in the apartment beneath which is of value, particularly where the earth has been filled in.

With artificial stone or concrete continuous arches; that is, made in one piece in length and breadth, distinctive om my sectional arches, the footings and haunches being several times thicker than at the crowns, the footings e much greater body from their increased thickness and consequent increased shrinkage strength, contract and draw themselves at the expense of cracking and separating the thinner and weaker connecting or bridging crown parts; e tensile strain thus produced is in excess of the resisting strength of the material, and it cracks.

In Jackson's sectional arches, the shrinkage is urged by the wedging keystone parts, employing the material in s great compressive strength—thirty-five times greater than its tensile strength.

In San Francisco there are many combined artificial stone sidewalks and arches, which are continuous (not distinct) arches. Most of them are cracked and disfigured from the cause described.

In support of the before-mentioned facts respecting the innate destructibility of concrete arches when made continuous instead of in sections, I will quote from the standard work, entitled, "Manufacture of Portland Cement," by W. H. Reid, C. E., of London, in the part relating to continuous concrete arches:

"In bridge building of concrete, the arch should be constructed of blocks of geometrical form, thereby realizing the whole strength and safety of the principle."

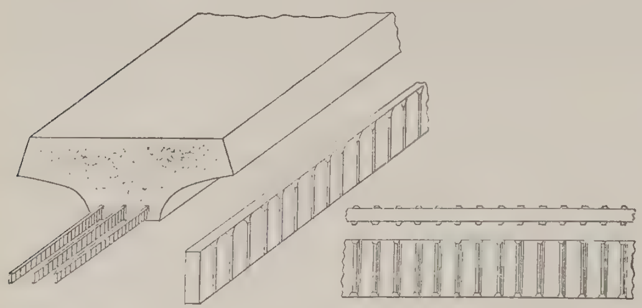


Fig. a.

Figure *a* is a perspective, side, and top views, of one form of Hyatt's iron or steel ties such as are used in Plates 2 and 4. The illustration to the left is the end of a concrete supporting beam as described and shown in Plate 2, with the end of the concrete cut away, the Hyatt ties projecting through, when the concrete is properly made and ties suitably embedded, the tie metal will invariably tear asunder before loosening in the concrete bond.

CONCRETE MIXTURE

First provide tarred paper or waterproof cloth and lay it on the centers and all parts on which the concrete is to be laid, the same to be water-tight to prevent the escape of moisture from the concrete.

For the footings of the arches in which the Hyatt ties are to be built, from the bottom up to top of ties, to be of a mixture of one volume of the best Portland cement to four volumes of clean, coarse, sharp gravel, free from dirt or loam, to be thoroughly mixed ***with a small quantity of water.*** After being well compacted, scratch the top of the layer and moisten, and from there compact in layers every four inches to within one and one-quarter inches of the top or sidewalk surface. This mixture to be in part a cement mortar, as follows [to be mixed after with an aggregate]: consisting of one part best Portland cement to three parts of clean coarse sharp gravel that will pass through a three-sixteenth inch mesh, to be mixed with a small quantity of water, gradually applied with a rose sprinkler in every case, otherwise the cement will float away. After water has been applied to the cement it is to be thoroughly mixed by several times turning over with shovels, incorporating the parts so that the surfaces of the gravel are entirely coated with the cement, ***the water*** to be applied after the cement is well mixed with the gravel and then to be well mixed again; this forms a stiff cement mortar of a consistence like quite damp or moist earth resulting from the small quantity of water used. Then measure in another place either three volumes of clean broken granite, bluestone, basalt rock, or equivalent in value angular stone chips that will pass through a three-inch ring. Wet thoroughly so as to coat well the surfaces of the stone before mixing, then thoroughly mix it by repeated turning with shovels in the before-described mortar. The cement mortar will more than coat the surfaces, fill the pores, and interstices of the stone chips. The cementing material or mortar must be used immediately after mixing; never mix a batch and the men go to dinner; if so ***it must not be used.*** Delay after mixing injures its strength. Before a new layer is added the previous one must have its surface well scratched over and moistened, otherwise it will not properly unite as a whole. The top or sidewalk surface, one and one-quarter inches thick, to be of equal parts of best Portland cement and gravel or sand, finish on top usual with artificial stone sidewalks.

Hyatt's Patent Metallic Ties consist of iron or steel bars or rods with roughened surfaces over their length, or they may have protuberances, raised portions, depressions, crimped, corrugated, or other holding surfaces, distinctive from the plain iron or steel rod or bar or their equivalent, to hold them over their length in the surrounding concrete. Or they may be flat or other bars or their equivalent with pins or wires passing through them.

With a bowstring girder the tie may be dependent on the end fastenings only, but with a beam proper, ***the tie must be held in every part over its length*** in effect as the bottom flange is riveted to the web of

a made-up iron beam. It is well known that the compressive force resisted on the upper flange of a girder, and the tensile strain resisted on the lower flange, increases progressively from the ends to the middle of the length. In Warren and other open girders each triangle or bay must be proportioned to meet the increased strains progressively from the ends to the center of the span, and each held in place. For this reason a smooth tie rod built in the bottom of a concrete beam and having end plates fails to be of service.

The credit of this great discovery, of the power of Portland cement concrete to hold in its embrace a metallic tie or ties having roughened, or equivalent-holding surfaces, and the application of the tie to the weak part of a concrete beam or construction to be employed on the beam principle, to supply the needed tensile strength to balance its comparative enormous compressive strength, making both parts a unit in resistance, ***is wholly and solely due to that great inventor and world benefactor, Thaddeus Hyatt,*** whose name will long be remembered after he has passed on and joined the great majority.

The results of a large number of these scientific experiments, about fifty in number, are recorded in his valuable, instructive and interesting work published in 1878, entitled, ***"Portland Cement Combined with Iron as a Building Material,"*** which is to be found in several of our public libraries.

An explanation of the forces exerted on a single beam may not be out of place. When a straight beam or girder is subjected to a bending stress it becomes more or less curved, by virtue of which the lower part is lengthened and the upper part is shortened in proportion to the depth of the beam and the difference in length between the radii of the curves. Were the beam made up of horizontal layers the effect of the stress would be to cause these to slide one upon the other, but the beam being solid the particles are held together by their own cohesion, the shearing strains being thus opposed by the cohesive force. **The primary strains in the beam** on the lines of compression and tension being upon curved lines, the disturbed particles must of necessity tend to arrange themselves in harmony with the radial lines of circles, all below the neutral axis seeking extension and all above compression. An illustration referring to Figure 1 represents the side view of a straight beam or structure on the beam principle, to be subjected to transverse strain when loaded and resting on end supports, the line x-y representing the neutral axis when loaded, being the dividing line between where the compressive force ceases and the tensile strain begins, the greatest force and strain being at the extremes from the neutral axis. **The imaginary vertical lines are at right angles with the bottom of the beam;** this is before the beam is loaded. The distance from any two of the lines of e, at the top, is the same distance from any two lines of f at the bottom. The length of the beam at top and bottom is equal.

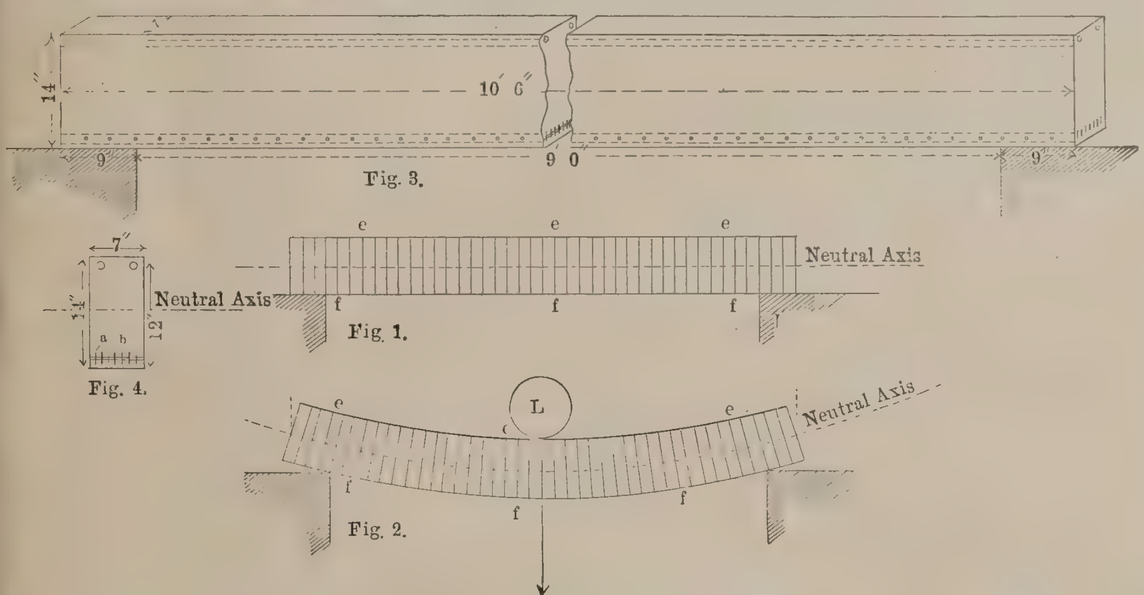


Fig. 3.
Fig. 1.
Fig. 4.
Fig. 2.

Figure 2 represents Figure 1 subjected to a severe bending stress curved by the load L, which has caused great deflection. The vertical imaginary lines e, f, in Figure 1, have become radial lines in Figure 2, radiating from a center to the curve of the bottom of the beam.

The distance from f to f at the bottom of the beam in Figure 2 is greater than in Figure 1, the thrust force causing the disturbed particles to extend the greatest at the bottom, and gradually diminishing up to the neutral axis, where it ceases, and from there the compressive force begins and gradually increases till the top surface is reached, which is the greatest, **and the distance from e to e is shortened; the neutral line x-y being the original length of the beam,** providing the two opposite forces have been equal in resistance.

It is evident that when the beam is loaded and the imaginary lines e and f are held in their vertical position and do not become radial lines, there can be no deflection of the beam, and its integrity remains intact.

Mr. Hyatt, knowing the great resisting compressive strength of Portland cement and Portland cement concret and the great disparity in its relative feeble tensile resistance, united iron or steel in such a way as to bind the to the weak part of the concrete body, in resisting separation along the bottom of the beam or structure, **so as t furnish all the tensile strength needed below the neutral axis to balance the compressive resistance above th neutral axis.**

Of the several experiments made by the writer on Portland cement concrete beams combined with Hyatt metallic ties to supply the needed tensile strength, will cite the one shown in Figures 3 and 4, which produce results corresponding with similar experiments.

Figure 3 is a longitudinal view of the beam tested. Figure 4 is a cross section, seven inches wide, fourtee inches deep and ten feet six inches long. Distance between supports nine feet, x-y representing the neutral axis.

At one-half inch up from the bottom was built in three of ¼ x 1 inch and four of ⅛ x 1 inch wrought-iron bar extending the length of the beam, and at every three inches from centers a one-quarter inch round iron rod extende through these seven bars, same as shown in cross section Figure 4 and longitudinally by the dots in Figure 3. Thes Hyatt ties were used for this experiment, instead of those with projections formed on the bars as shown in Figure a an Plate 4. The total weight of the wrought-iron was but 46½ pounds; this resisted the tensile strains until the bean was broken. The area of cross sections of all these wrought-iron ties to resist the tensile strain of the beam, afte deducting the holes for the one-quarter inch rods, **equals a bar one inch square, or equal the bottom flange of a wrought-iron beam, eight inches wide by one-eighth inch thick.**

The top of the beam being but seven inches wide of concrete, and seven inches up from the neutral axis, was without due consideration, regarded insufficient in strength to resist the compressive force, to balance the tensile strai of ties at the bottom, and for this reason had built in near the top of the beam two cast-iron rope mouldings, eac three-quarter inches in diameter, shown in the end in Figure 4, and along the length and end near the top in Figur 3. I have since found this provision was unnecessary, as the concrete material above the neutral axis of the beam wa about sufficient to balance the opposite strain of the ties below the neutral axis.

The load was of pig iron, piled uniformly over the length of the beam, ending in a vertical line over the insid of the supports.

When 20,695 pounds had been laid on it deflected one-sixteenth inch, or 38-100 of what broke it.

15½	tons,	30,989	pounds;	deflection	3-32	inch
18	"	36,045	"	"	1-4	"
19	"	38,113	"	"	9-32	"
20	"	40,056	"	"	3-8	"
21	"	42,062	"	"	1-2	"
22	"	44,077	"	"	9-16	"
		45,678	"	"	21-32	"
23	"	46,115	"	"	23-32	"
——	tons,	47,018	pounds;	deflection	3-4	inch
24	"	47,996	"	"	13-16	"
24½	"	49,001	"	"	7-8	"
25	"	50,054	"	"	15-16	"
26	"	52,062	"	"	1 1-8	"
		52,692	"	"	1 3-16	"
26 8/10	"	53,654	"	broke by separation; ties torn asunder.		

The pig iron was closely piled across the beam, and was seven feet six inches above the beam. The broke beam is now in front of 228 First street. This, with other experiments by the writer, was made in the presence o several scientific gentlemen, who exhibited great interest in the experiments.

The increased strength of this beam, compared to a wrought-iron beam with a bottom flange equaling the are of all the ties in the concrete beam, may be accounted for by its solidity, more rigid against lateral deflection than a web beam, and the resisting parts act together. The punched holes weaken the iron, and the rivets do not in all case fill up the holes in a wrought-iron beam.

In computing the strength of this concrete beam (which bears out that of other trials) exceeding in strength a properly proportioned made-up wrought-iron beam of an area of bottom flange equaling the area of all the ties in the

concrete beam, I find the constant of two hundred suitable for a breaking distributed load, and propose in future calculations to adopt that figure as a permanent constant. We have the breaking distributed load by such multiple as follows:

$$\frac{\overset{\text{Area of Hyatt's ties equal to area of bottom flange of iron beam}}{1 \text{ inch}} \times \overset{\text{Depth}}{14 \text{ inches}} \times \overset{\text{Constant}}{200}}{9 \text{ feet} \times 12 = 108 \text{ inches}} = \frac{2800}{108} = 26 \text{ tons}$$

By distributed load.

The beam broke at twenty-six and eight-tenths tons, of 2,000 pounds to ton.

In order that the top of the beam or all above the neutral axis may have a compressive strength to balance the tensile strength of the ties at the bottom, I have concluded for every inch of wrought-iron ties below neutral axis there should be twenty-eight inches of Portland cement concrete of the mixture given above the neutral axis. For this reason, I have found by experiment that a mixture of one volume of Portland cement with five volumes of poor aggregates (part of which were large round pebbles) six months old, crushed at about 2,600 pounds per square inch; and the sidewalk surface in the combined arch and sidewalk construction being one and a quarter ($1\frac{1}{4}$) inches thick of equal proportions of Portland cement and gravel, has a compressive resistance of over 4,000 pounds per inch; therefore, I consider it proper to take it as a whole at 1,800 pounds per square inch as a mean compressive resistance of the concrete above the neutral axis.

We have taken the Hyatt wrought-iron ties at the tensile strength of 50,000 pounds per square inch.

1,800 ℔s. ÷ 50,000 ℔s = 28 inches of concrete of the mixture given, to balance one inch of Hyatt's iron ties.

In proportioning the parts of any concrete construction to be employed on the beam principle, let the part above the neutral axis to be subjected to compression be in the ratio of twenty-eight inches to every inch of Hyatt ties below the neutral axis. If there is not a sufficient quantity of concrete material, employ a cast-iron rope moulding or any other continuous piece of cast iron, with roughened surface like a Hyatt tie, at the rate of 54-100 of a square inch in the smallest section of the cast iron to every inch of wrought-iron tie below, as cast iron resists compression at the rate of 93,000 pounds per square inch or nearly double the tensile strength (50,000 pounds) of the wrought-iron tie.

Or if Hyatt's (a wrought-iron tie) should be used to make up for this deficient compressive resistance, use one and 4-10 inches to every one inch of tie below, as wrought iron has a compressive resistance of but 36,000 pounds per square inch, while its tensile strength is 50,000 pounds.

For computing the breaking distributed weight of Hyatt's concrete beam, also combined concrete sidewalk and arch of segmental form and in sections and flat arches—plat-band as well—and other constructions on the beam principle at the age of not less than six months.

First proportion the parts as before described in their respective resistances to compression and extension.

Multiply the sectional area of all the Hyatt ties, of any particular section, by the depth from top surface down to bottom of ties, and multiply that result by a constant of two hundred for a distributed load, or one hundred for a central load; and divide by the distance between supports in inches, the quotient will be the breaking load in net tons.

As this concrete beam principle bears a relation for strength, when it is six months old, to that of a wrought-iron beam, it would be proper to employ it at but one-third its breaking load, usual with wrought-iron beams, **the difference between that and one-fourth is given as additional strength in favor of the concrete beam.**

Formulæ for computing the strength of a concrete beam, also the supporting beam sections of a combined concrete sidewalk and arch made in sections, flat arches made in sections, concrete foundations forming cellar floors to buildings, and concrete walls subjected to lateral pressure and like constructions on the beam principle, resting upon or resisted by end supports.

A—Area of Hyatt's ties in inches.

D—Depth from top surface to bottom of ties.

C—Constant of two hundred for distributed load.

L—Length between supports in inches.

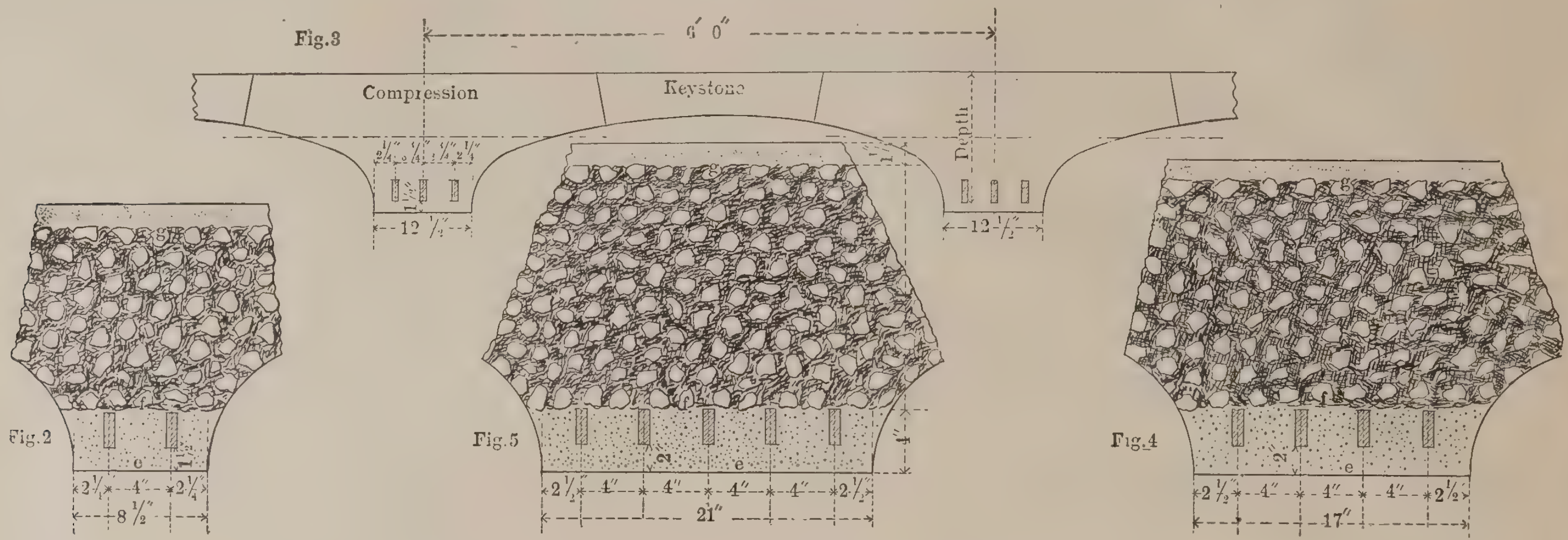
Y—Breaking distributed load.

Z—Breaking central load. Employ at one-quarter breaking load.

$\frac{A\ D\ C}{L} = y \times \frac{1}{4} =$ Employed load.

EXAMPLE

To ascertain the load of a beam section, of a combined sidewalk and arch of segmental form with impose load like the following plate. Let the distance between the Hyatt ties, also the distance from the outside, and th distance up from the bottom according to the number used, be in each case as marked below :



The distance from center to center of beams, in preceding figure, six feet.
Distance between supports, say twenty feet (not the whole length).
The average weight per square foot of combined arch and sidewalk, 90 pounds.
Imposed load subject to impact, 1,260 pounds per square yard, or 140 pounds per square foot.
90 + 140 make total weight per square foot, 230 pounds.

Area of sidewalk and arches to be supported on each beam section, the weight includes that of the beam.
6 feet x 20 feet=120 feet x 230 pounds=27,600 pounds, or 13 8-10 tons.

The Hyatt ties we have on hand at present, of the kind shown on Plate a and Plate 4, are :
A is 2¼ inches x ⅝ inch=area, 1 41-100 inches.
B is 2¼ inches x ¾ inch=area, 1 68-100 inches.
The Hyatt flat bars threaded on ¼ inch rods we make to order.

To ascertain the strength ot a section employing three of A Hyatt's iron ties to resist the tensile strain.
A, is 2¼ x ⅝ inches=4 23-100 inches.
Depth from bottom of ties to top 16 inches.
Distance between supports, 20 feet or 240 inches, the computation is as follows :

$$\frac{4\tfrac{23}{100} \times 16 \times 200}{240} = \frac{13{,}536}{240} = 56 \text{ 2-10 tons}$$

56 2-10 tons breaking distributed load, employ at ¼=14 tons.
Above calculation indicates the load to be carried as 13 8-10 tons.

ADAPTABILITY TO FIRE-PROOF CONSTRUCTION

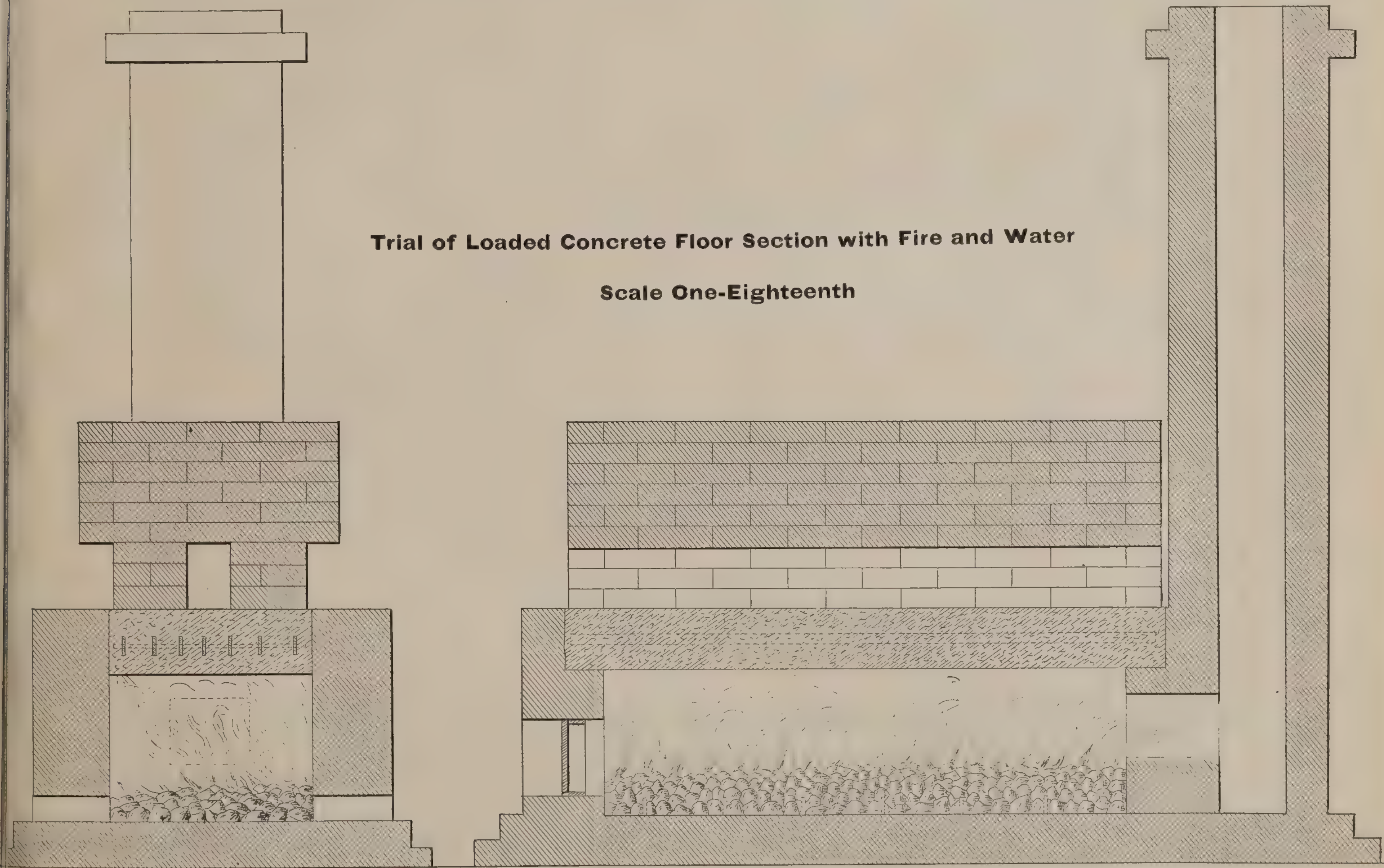
The following is an extract from Mr. Hyatt's book before mentioned, entitled, "Portland Cement Concrete Combined with Iron as a Building Material," pages 19 and 20.

To ascertain the limits of expansion and contraction of Portland cement within definite ranges of temperature, trial sticks of cement were made and heated, the expansion of the same being ascertained by placing the tests between two fixed points, space being allowed between, the

variations in which were ascertained by means of tapered pieces, which were then measured by Holtzapffel's Thousand gauge. ***The result was found to be a lineal expansion of .00137 for 180 degrees of heat as compared with .00140 for wrought iron,*** a result so near that the expansion may be considered the same; but in order to prove the result practically, blocks of cement concrete, fourteen inches long and four inches deep by three inches wide were made, in which bars of iron were imbedded, the bars varying in size 2 x 1-32 of an inch to 2 x 2 inches and 12 inches long. On testing these by fire no difference in effect was found to be produced on the concrete by the different masses of metal contained within them. As a final test bars of iron two feet long by one-half inch thick were imbedded in blocks of concrete; these blocks on being exposed to the red heat of a furnace for six hours, were found to be entirely sound and good when taken out; the synchronism existing between the expansion of the two materials, whatever the size of the metal, was thus placed beyond question, and in respect to this combining concrete with iron for building purposes the two materials may be regarded as practically homogeneous. These results, as may be supposed, were in the highest degree satisfactory and assuring.

In order to test the effect of fire and water to a real floor of the concrete construction, combined with iron, a section of one sufficiently large to leave no doubt as to the result of fire and water to a real floor in actual use. Accordingly, a furnace was built as represented in the following plate, the top being a slab or floor section six feet long by two feet wide, and seven and one-half inches thick. The tie-metal in gridiron form was placed at the middle of the thickness, three inches of concrete being above and three inches below the metal.

The furnace was made with a range of air-holes on either side, to insure perfect combustion and intense heat.



Loose bricks were piled upon the furnace top until a load was obtained of 300 pounds per square foot over the whole surface, the deflection being with this load 1-32 of an inch in a span of five feet.

The fuel was arranged to form an incandescent bed six inches thick at twelve inches below the under face of the concrete slab.

The fire was kindled at 6 o'clock in the morning, had by 11 become an intense heat perfectly uniform over the entire surface, and the bottom of the concrete was also at a glowing red heat, all over.

At this intensity the fire was kept up until 4 p. m., a period of ten hours from the lighting of it. During th time the slab had deflected three-eighths of an inch.

A stream of cold water was now thrown forcibly against the bottom of the slab for a period of fifteen or twen minutes, by means of a garden force pump, and the load then removed.

On examining the underside of the section it was found uninjured; and the next morning, being then entire cold, the deflection had disappeared—***the slab had returned to its former level.***

In order to confirm these results a second trial was made. This time the load was left upon the slab, whic during the firing, deflected as before, ***but upon cooling returned to its original level, lifting th load with it.*** In proof of the heat of the furnace it may be mentioned that in the course of this experime the faces of all the side bricks in actual contact with the fire were melted.

In addition to the experiments described others of less moment were made, as to the non-conducting power vrrious substances, such as plaster of Paris of different densities, and concretes more or less porous, also air spaces; th result of all being that the best material to protect the metal against heat was found to be that which was the stronge in compression, viz: Portland cement concrete of best quality, no advantage for any purpose being found from fibr of any kind, ***not even asbestos.*** Mr. Hyatt used 10 per cent of Flowers of Sulphur with the Portland cemen partially converting it to Sulphate of Lime, largely increasing its resistance to the destructive effects of fire.

How to proportion a CONCRETE BEAM, or a section of any CONCRETE con struction to be employed on the beam principle combined with Hyatt's ties.

It is equally applicable to brick constructions with the variation allowable fo the difference in strength between concrete and brick.

For concrete, first proportion the cross-section of the part of concrete construction to be employed on the bea principle, in its relative resistances to compressive force and tensile strain, as follows:

The upper half of the cross-section to be computed in square inches, and of this allot every 28 square inches concrete material to resist compressive force, to meet and balance each square inch of Hyatt's ties built in the botto section to be employed in resisting tensile strain.

If all the square inches of concrete in the top are found to be insufficient in compressive strength to balance th area of all the Hyatt ties in the bottom, the deficiency must be made up either with cast or wrought iron. The forme has a compressive strength of 93,000 pounds per square inch, while wrought iron has but 36,000 pounds. A cast-iro rope moulding may be used, computing its area in its least section, or any other shape of cast iron that has a holdin surface over its length as that of a Hyatt tie, and to be in the ratio of 54-100 of a square inch thus employed to ever square inch of Hyatt tie metal; or, if made up of a Hyatt's tie or ties, which, being of wrought iron when thus employe is deficient in compressive strength, and to be one and four-tenths inches to every square inch of the Hyatt ti metal in the bottom.

Should there be an excess of concrete material in the top part required to resist compression, it makes no diffe ence, as all computations of strength, after the beam has been proportioned, are based on the strength of the botto part, the part that resists tensile strain.

To find the area of Hyatt ties to be built in the bottom of a concrete beam to resis tensile strain, or in any concrete construction to be employed on the beam principle.

Multiply the depth (that is, from the top surface to the bottom of the ties) by a constant of 50 (which is for safe load employed at ¼ the breaking load) and divide that result by the distance between supports in inches, th quotient to divide into the load in tons to be carried, the product is the area in square inches of all the Hyatt's tie required for tensile strength.

D=Depth in inches from top surface to bottom of Hyatt ties.

C=Constant 50 being ¼ of breaking distributed weight of constant 200.

L=Distance between supports in inches.

W=Load to be carried in tons.

H = Area of Hyatt Ties

Area of Hyatt Ties = $\frac{D\,C}{L}$ = quotient ÷ W.

EXAMPLE

What is the required area of Hyatt ties to be employed in a concrete beam, or a combined concrete arch and idewalk beam? The depth from surface of sidewalk to bottom of ties in the footing of the arch being 16 inches; istance between supports 20 feet, and load to be carried 12 6-10 tons.

Depth Constant Tons

$$\frac{16 \times 50}{20 \times 12} = \frac{800 = 3.333 \div 12.600}{240 \text{ length in inches.}} = 3\ 8\text{-}10 \text{ inches, required area of Hyatt ties.}$$

SECOND EXAMPLE

What is the required area of Hyatt ties to be employed to furnish the tensile strength for a concrete flat arch, r a segmental arch, or a section of a cellar floor forming the foundation for all the walls as in Plate 4, or any other oncrete construction on the beam principle? Depth to bottom of ties, 16 inches; distance between supports, 24 feet; oad to be carried, 15 2-10 tons.

Depth Constant Tons

$$\frac{16 \times 50}{24 \times 12} = \frac{800 = 2.777 \div 15.2}{288 \text{ length in inches.}} = 5\tfrac{1}{2} \text{ inches area.}$$

To prove the correctness of this example by the first formula, what load will 5½ inches of Hyatt's ties sustain, mployed at one-fourth their strength along the bottom of a beam or footing of an arch, depth 16 inches, span 24 feet?

$$\frac{5\tfrac{1}{2} \times 16 \times 50}{24 \times 12} = 15\ 2\text{-}10 \text{ tons.}$$

The following is the average weight per square foot of a concrete segmental arch, its top surface forming an rtificial stone sidewalk, or for a fire-proof floor, including an imposed load usually computed for sidewalks:

Average weight of concrete arches with their top surface forming sidewalk, maximum, 90 lbs. per square foot.

Imposed load subject to slight impact, 1,260 pounds per square yard, or 140 pounds per square foot.

Total weight per square foot, 230 pounds.

The following are the different weights in tons computed at the above rate of 230 pounds per square foot of a idewalk and that part of the arch usually sustained by a beam, of different lengths and of various distances from center o center of arch, and of different depths; also, the area of cross-section of Hyatt ties required in each case, and selected rom the sizes of Hyatt ties we have at present to meet each requirement: (The ties are designated as "A" and "B.")

The size of Hyatt's Patent Iron Ties required for artificial stone sidewalks and arches combined,

OF SPANS VARYING FROM 12 to 25 FEET. A READY REFERENCE

Arches of 5 feet 6 inches from center to center
ie A = 2¼ x ⅝ = 1.41 in. area; weight per sq. ft. 5½ lbs
ie B = 2¼ x ¾ = 1.68 in. area; weight per sq. ft. 6¼ lbs

Dist. etw'n Sup-ports	Equal to square feet	Wgt. per foot lbs.	Total Weight in Tons	Depth f'm t'p surf'ce to bottom of tie	Area of ties required in ins.	Use Ties	Area
2 feet	66	230	7 6-10	16 in's	1.37	1A =	1.41
3 "	71½	"	8 2-10	16 "	1.59	1B	1.68
4 "	77	"	8 9-10	16 "	1.87	2A	2.82
5 "	82½	"	9 5-10	16 "	2.14	2A	2.82
6 "	88	"	10 1-10	16 "	2.42	2A	2.82
7 "	93½	"	10 7-10	16 "	2.73	2A	2.82
8 "	99	"	11 4-10	16 "	3.03	2B	3.36
9 "	104½	"	12	16 "	3.42	2B	3.36
0 "	110	"	12 6-10	16 "	3.78	3A	4.23
1 "	115½	"	13 3-10	16 "	4.19	3A	4.23
2 "	121	"	13 9-10	16 "	4.58	2B + 1A	4.77
3 "	126½	"	14 5-10	16 "	5.00	3B	5.04
4 "	132	"	15 2-10	18 "	4.90	3B	5.04
5 "	137½	"	15 8-10	18 "	5.30	3B	5.04

Arches of 5 feet 9 inches from center to center
Tie A = 2¼ x ⅝ = area 1.41 in. Weight per foot 5½ lbs
Tie B = 2¼ x ¾ = area 1.68 in. Weight per foot 6¼ lbs

Dist. betw'n sup-ports	Equal to square feet	Wgt. per foot. lbs.	Total weight in tons.	Depth f'm t'p surf'ce to bottom of tie	Area of ties required in ins.	Use ties	Area
12 feet	69	230	7 9-10	16 in's	1 4-10	1A =	1.41
13 "	74¾	"	8 6-10	16 "	1 6-10	1B	1.68
14 "	80½	"	9 3-10	16 "	2	2A	2.82
15 "	86¼	"	9 9-10	16 "	2 2-10	2A	2.82
16 "	92	"	10 6-10	16 "	2 5-10	2A	2.82
17 "	97¾	"	11 2-10	16 "	2 9-10	1A + 1B	3.09
18 "	103½	"	11 9-10	16 "	3 2-10	2B	3.36
19 "	109¼	"	12 5-10	16 "	3 5-10	3A	4.23
20 "	115	"	13 2-10	16 "	4	3A	4.23
21 "	120¾	"	13 9-10	16 "	4 4-10	2A + 1B	4.50
22 "	126½	"	14 5-10	16 "	4 7-10	3B	5.04
23 "	132¼	"	15 2-10	16 "	5 2-10	4A	5.64
24 "	138	"	15 9-10	16 "	5 7-10	2A + 2B	6.18
25 "	143¾	"	16 5-10	16 "	6 2-10	1A + 3B	6.45

Arches of 6 feet from center to center
Tie A = 2¼ x ⅝ = area 1.41 in. Weight per foot 5½ lbs
Tie B = 2¼ x ¾ = area 1.68 in. Weight per foot 6¼ lbs

Dist. betw'n sup-ports	Equal to square feet	Wgt. per foot. lbs.	Total weight in tons	Depth f'm t'p surf'ce to bottom of tie	Area of ties required in ins.	Use ties	Area
12 feet	72	230	8 3-10	16 in's	1.50	1B =	1.68
13 "	78	"	9	16 "	1.76	2A	2.82
14 "	84	"	9 7-10	16 "	2.04	2A	2.82
15 "	90	"	10 3-10	16 "	2.32	2A	2.82
16 "	93	"	11	16 "	2.64	2A	2.82
17 "	102	"	11 7-10	16 "	3.00	1A + 1B	3.09
18 "	103	"	12 4-10	16 "	3.34	2B	3.36
19 "	114	"	13 1-10	16 "	3.73	3A	4.23
20 "	120	"	13 8-10	16 "	4.14	3A	4.23
21 "	126	"	14 5-10	16 "	4.57	1A + 2B	4.77
22 "	132	"	15 2-10	16 "	5.00	3B	5.04
23 "	133	"	15 9-10	18 "	4.90	3B	5.04
24 "	144	"	16 6-10	18 "	5.30	3A + 1B	5.91
25 "	150	"	17 2-10	18 "	5.71	3A + 1B	5.91

The Size of Hyatt's Patent Iron Ties required for Artificial Stone Sidewalk and Arch Combined

Arches of 6 feet 3 inches from center to center
Tie A=2¼ x ⅝=1.41 in. area; Weight per ft. 5½ lbs
Tie B=2¼ x ¾=1.68 in. area; Weight per ft. 6¼ lbs

Dist. betw'n Sup-ports	Equal to square feet	Wgt. per foot lbs.	Total Weight in Tons	Depth f'm t'p surf'ce to bottom of Tie	Area of Ties re-quired in ins.	Use Ties	Area
12 feet	75	230	8 6-10	16 in's	1.55	1B =	1.68
13 "	81¼	"	9 3-10	16 "	1.81	2A	2.82
14 "	87½	"	10	16 "	2.1	2A	2 82
15 "	93¾	"	10 8-10	16 "	2.43	2A	2.82
16 "	102	"	11 7-10	16 "	2.8	2A	2.82
17 "	106¼	"	12 2-10	16 "	3.11	1A+1B	3 09
18 "	112½	"	12 9-10	16 "	3.43	3A	4.23
19 "	118¾	"	13 7-10	16 "	3.9	3A	4.23
20 "	125	"	14 4-10	16 "	4.02	3A	4.23
21 "	131¼	"	15 1-10	16 "	4.76	1A+2B	4.77
22 "	137½	"	15 8-10	18 "	4.63	1A+2B	4.77
23 "	143¾	"	16 5-10	18 "	5.06	3B	5.04
24 "	150	"	17 2-10	18 "	5.50	4A	5.64
25 "	156¼	"	18	18 "	6.00	2A+2B	6.18

Arches of 6 feet 6 inches from center to center
Tie A=2¼ x ⅝=1.41 in. area; Weight per ft. 5½ lbs
Tie B=2¼ x ¾=1.68 in. area; Weight per ft. 6¼ lbs

Dist. betw'n Sup-ports	Equal to square feet	Wgt. per foot lbs.	Total Weight in Tons	Depth f'm t'p surf'ce to bottom of Tie	Area of Ties re-quired in ins.	Use Ties	Area
12 feet	78	230	9	16 in's	1.62	1B =	1.68
13 "	84½	"	9 7-10	16 "	1.89	2A	2.82
14 "	91	"	10 5-10	16 "	2.21	2A	2.82
15 "	97½	"	11 2 10	16 "	2.52	2A	2.82
16 "	104	"	12	16 "	2.88	1A+1B	3.09
17 "	110½	"	12 7-10	16 "	3 24	2B	3.36
18 "	117	"	13 5-10	16 "	3.64	2A+1B	4.50
19 "	123½	"	14 2-10	16 "	4.05	2A+1B	4.50
20 "	130	"	15	16 "	4.5	2A+1B	4.50
21 "	136½	"	15 7-10	16 "	4.95	3B	5.04
22 "	143	"	16 5-10	18 "	4.84	3B	5.04
23 "	149½	"	17 2-10	18 "	5.27	4A	5.64
24 "	156	"	17 9-10	18 "	5.72	3A+1B	5.91
25 "	162½	"	18 7-10	18 "	6.23	1A+3B	6.45

Arches of 6 feet 9 inches from center to center
Tie A=2¼ x ⅝=1.41 in. area; Weight per ft. 5½ l
Tie B=2¼ x ¾=1.68 in. area; Weight per ft. 6¼ l

Dist. betw'n Sup-ports	Equal to square feet	Wgt. per foot lbs.	Total Weight in Tons	Depth f'm t'p surf'ce to bottom of Tie	Area of Ties re-quired in ins.	Use Ties	Ar
12 feet	81	230	9 3-10	16 in's	1.67	1B =	1.
13 "	87¾	"	10 1-10	16 "	1.97	2A	2.8
14 "	94½	"	10 9-10	16 "	2.29	2A	2.8
15 "	101¼	"	11 6-10	16 "	2.61	2A	2.8
16 "	108	"	12 4-10	16 "	2.97	1A+1B	3.0
17 "	114¾	"	13 2-10	16 "	3.36	2B	3.3
18 "	121½	"	14	16 "	3.78	2A+1B	4.5
19 "	128¼	"	14 7-10	16 "	4.19	2A+1B	4.5
20 "	135	"	15 5-10	16 "	4.65	2B+1A	4.7
21 "	141¾	"	16 3-10	18 "	4.62	2B+1A	4.7
22 "	148½	"	17 1-10	18 "	5.01	3B	5.0
23 "	155¼	"	17 8-10	18 "	5.46	4A	5 6
24 "	162	"	18 6-10	18 "	6.00	2A+2B	6.1
25 "	168¾	"	19 4-10	18 "	6.46	1A+3B	6.4

These Ties are sold to Artificial Stone and Concrete Makers by the pound, but only with the understanding of strict compliance with directions herein given.

Arches of 7 ft. 0 inches from center to center
Tie A=2¼ x ⅝=1.41 in. area; Weight per ft. 5½ lbs
Tie B=2¼ x ¾=1.68 in. area; Weight per ft. 6¼ lbs

Dist. betw'n Sup-ports	Equal to square feet	Wgt. per foot lbs.	Total Weight in Tons	Depth f'm t'p surf'ce to bottom of Tie	Area of Ties re-quired in ins.	Use Ties	Area
12 feet	84	230	9 7-10	16 in's	1.75	2A =	2.82
13 "	91	"	10 5-10	16 "	2 04	2A	2.82
14 "	98	"	11 3-10	16 "	2.37	2A	2.82
15 "	105	"	12 1-10	16 "	2.72	2A	2.82
16 "	112	"	12 9-10	16 "	3.09	1A & 1B	3.09
17 "	119	"	13 7-10	16 "	3.49	3A	4.23
18 "	126	"	14 5-10	16 "	3.91	3A	4.23
19 "	133	"	15 3-10	16 "	4.33	2A & 1B	4.50
20 "	140	"	16 1-10	16 "	4.71	1A & 2B	4.77
21 "	147	"	16 9-10	18 "	4.73	1A & 2B	4.77
22 "	154	"	17 7-10	18 "	5.19	4A	5.64
23 "	161	"	18 5-10	18 "	5.67	4A	5.64
24 "	168	"	19 3-10	18 "	6.17	2A+2B	6.18
25 "	175	"	20 1-10	18 "	6.70	4B	6.72

Arches of 7 feet 4 inches from center to center
Tie A=2¼ x ⅝=1.41 in. area; Weight per ft. 5½ lbs
Tie B=2¼ x ¾=1.68 in. area; Weight per ft. 6¼ lbs

Dist. betw'n Sup-ports	Equal to square feet	Wgt. per foot lbs.	Total Weight in Tons	Depth f'm t'p surf'ce to bottom of Tie	Area of Ties re-quired in ins.	Use Ties	Area
12 feet	88	230	10 1-10	16 in's	1.82	2A=	2.82
13 "	95⅓	"	11	16 "	2.15	2A	2.82
14 "	102⅔	"	11 8-10	16 "	2.48	2A	2.82
15 "	110	"	12 6-10	16 "	2.84	2A	2.82
16 "	117⅓	"	13 5-10	16 "	3.24	2B	3.36
17 "	124⅔	"	14 3-10	16 "	3.64	3A	4.23
18 "	132	"	15 2-10	16 "	4.10	3A	4.23
19 "	139⅓	"	16	16 "	4.56	1A & 2B	4.77
20 "	146⅔	"	16 9-10	18 "	4.51	2A & 1B	4.50
21 "	154	"	17 7-10	18 "	5.00	3B	5.04
22 "	161⅓	"	18 5-10	18 "	5.43	4A	5.64
23 "	168⅔	"	19 4-10	18 "	5.95	2A & 2B	6.18
24 "	176	"	20 2-10	18 "	6.46	1A & 3B	6.45
25 "	183⅓	"	21 1-10	19 "	6.66	4B	6.72

Arches of 7 feet 8 inches from center to center
Tie A=2¼ x ⅝=1.41 in. area; Weight per ft. 5½ lt
Tie B=2¼ x ¾=1.68 in. area; Weight per ft. 6¼ lt

Dist. betw'n Sup-ports	Equal to square feet	Wgt. per foot lbs.	Total Weight in Tons	Depth f'm t'p surf'ce to bottom of Tie	Area of Ties re-quired in ins.	Use Ties	Are
12 feet	92	230	10 6-10	16 in's	1.91	2A =	2.8
13 "	99⅔	"	11 5-10	16 "	2.24	2A	2.8
14 "	107⅓	"	12 3-10	16 "	2.58	2A	2.8
15 "	115	"	13 2-10	16 "	2.97	1A+1B	3.0
16 "	122⅔	"	14 1-10	16 "	3.38	2B	3.3
17 "	130⅓	"	15	16 "	3.83	3A	4.2
18 "	138	"	15 9-10	16 "	4.29	2A & 1B	4.5
19 "	145⅔	"	16 7-10	16 "	4.76	1A & 2B	4.7
20 "	153⅓	"	17 6-10	18 "	4.70	1A & 2B	4.7
21 "	161	"	18 5-10	18 "	5.18	4A	5.6
22 "	168⅔	"	19 4-10	18 "	5.69	3A & 1B	5.9
23 "	176⅓	"	20 3-10	18 "	6.22	1A & 3B	6.4
24 "	184	"	21 2-10	19 "	6.43	1A & 3B	6.4
25 "	191⅔	"	22	19 "	6.6	4B	6.7

Arches of 8 feet 0 inches from center to center
Tie A=2¼ x ⅝=1.41 in. area; Weight per ft. 5½ lbs
Tie B=2¼ x ¾=1.68 in. area; Weight per ft. 6¼ lbs

Dist. betw'n Sup-ports	Equal to square feet	Wgt. per foot lbs.	Total Weight in Tons	Depth f'm t'p surf'ce to bottom of Tie	Area of Ties re-quired in ins.	Use Ties	Area
12 feet	96	230	11	16 in's	1.98	2A =	2.82
13 "	104	"	12	16 "	2.34	2A	2.82
14 "	112	"	12 9-10	16 "	2.71	2A	2.82
15 "	120	"	13 8-10	16 "	3.10	1A+1B	3.09
16 "	128	"	14 7-10	16 "	3.53	3A	4.23
17 "	136	"	15 6-10	16 "	3.98	3A	4.23
18 "	144	"	16 6-10	16 "	4.48	2A+1B	4.50
19 "	152	"	17 5-10	16 "	4.99	3B	5.04
20 "	160	"	18 4-10	J8 "	4.91	3B	5.04
21 "	168	"	19 3-10	18 "	5.40	4A	5.64
22 "	176	"	20 2-10	18 "	5.92	3A+1B	5.91
23 "	184	"	21 2-10	18 "	6.50	4B	6.72
24 "	192	"	22 1-10	20 "	6.36	1A+3B	6.45
25 "	200	"	23	21 "	6.57	4B	6.72

The following are extracts taken from the standard works, entitled, "Notes on Concrete and Works in Concrete, by John Newman, C. E.; "Coignet-Beton and Artificial Stone," by General Q. A. Gilmore; "Portland Cement fo Users," by Henry Faija, C. E.; and "Practical Treatises on Portland Cement, and on Concrete," by Henry Reid, C. E

I

"Portland cement concrete has become one of the most important materials in construction and can be use with absolute confidence that the work will be of great hardness and strength and will not deteriorate, providing th necessary care in the selection, storing, proportions, mixing and depositions which experience has proved to b requisite."—NEWMAN.

II

"The valuableness of Portland cement is its power of firmly uniting other substances, its cohesiveness, dura bility and adaptability to be moulded in any form with a rapidity of execution unattainable with brickwork o masonry."—NEWMAN.

III

"Portland cement preserves iron from corrosion. Among its various uses is that to prevent oxidation in the holds of iron vessels. Portland cement has been extensively used in England in the insides of iron ships to preserve the iron from corrosion, and after eighteen years' use it has been dug out of an iron ship when the red lead, paint and the skin of the iron were as sound as on the day they were put there. It has been successfully used for preserving ship's iron bottoms."—REID.

IV

"The degree of strength, hardness, and consequent durability attained by Portland cement concrete in setting is dependent on the quality of Portland cement, the kind and quality of sand or gravel and broken stone employed, the quantity of water used and the method and degree of manipulation."—GILMORE.

V

Mixing Concrete or Artificial Stone Paste—"The ingredients should be thoroughly and uniformly mixed together. It is found in practice that a combined pressing and rolling motion gives the best results."—GILMORE

VI

"The most important consideration is the proper admixture of the ingredients. The thorough incorporation of the cement, sand, gravel or broken stone, with a small amount of water, is the A B C of the process."—REID.

VII

"For house-building, a good cement mortar may be made by a mixture of five or six of gravel or shingle with one of good Portland cement, adding a small portion of sand to fill up vacuities of the compound. The whole of these ingredients should be well mixed, first in a dry state, and when this is thoroughly done, then a quantity of water added, only sufficient by which it would be suitable to render the material plastic enough to be put into moulds. When the water is added it should be gradually poured on the dry mixture by a rose jet. Concrete when so treated, and carefully and thoroughly mixed, will be immensely superior in quality to the ordinary sloppy and roughly handled mixture called concrete."—REID.

VIII

"The matrix must be incorporated with the solid ingredients by a thorough and prolonged mixing, producing artificial stone paste, *decidedly loose, wanting in cohesion in character* until compacted by pressure in which every grain of sand and gravel is coated by a a film of thin paste. This pasty tenacious mass will remain in almost any form into which it is beaten, and this condition should be allowed with minimum of water and in the shortest possible time—the quicker the better."—GILMORE.

IX

"The great enemy of Portland cement is loam, clay or dirt, and it is of the first importance that the aggregates and sand should be perfectly clean, in order that the best results may be obtained."—FAIJA.

X

"The materials with which the Portland cement is to be incorporated should be thoroughly and well mixed with it *before the water is added.* The water should *be gradually added* by a rose nozzle sprinkler and shoveled over while the water is sprinkled over it, so that all the aggregates, as well as the cement, may be thoroughly and evenly wetted before the mass is laid in position. *If the water is added too quickly it washes and floats away the cement from the aggregates."*—FAIJA.

XI

"When Portland cement is mixed with too much water the particles are suspended and they lose all cohesion. The consistency of the mixture, from the proper small quantity of water used, should have the appearance of moist sand, quite granular to the touch, showing no indication of the cementitious and indurating properties which it possesses."—REID.

XII

"If an excess of water is used that which does not chemically combine with the cement will remain suspended in the mass and be a source of weakness, while if an insufficient quantity is used, a chemical action will have been set up without the possibility of its being completed, and as a result will be equally fatal to the strength of the cement."—REID.

XIII

"No Portland cement or concrete after being mixed should be **softened or remixed with an addition of water to enable it to be deposited in the work, as setting operations are most seriously affected by such action."**

XIV

"If water enough is used to make the mixture plastic **like mason's mortar the tensile strength is largely diminished in proportion to the excessive amount of water used. If too much water be used the mixture cannot be suitably rammed; if too little it will be deficient in strength."**—GILMORE.

XV

"A cement made just so stiff that it can be rammed with either wood or iron rammers until the water is brought to the surface was generally found to give the best results.

"Most cements take from seventeen to eighteen per cent. of water. A quick-setting cement requires more than a slow-setting one, varying from sixteen to twenty per cent.

"It is explained that a minimum of water gives the best results, so far as the actual strength of the cement is concerned, but there are certain things to consider which should determine the amount of water to be used. There is in the first instance the nature and size of the aggregates, for it is evident that a broken brick or a porous stone would absorb a large quantity of water and thus take it from the cement, while a shingle or ballast would absorb but little, and consequently a larger quantity of water would be required to form a solid concrete when using the former than when using the latter. If the concrete is to be used for foundations the nature of the soil should be considered, for if it is of a clayey or other non-porous nature, a less amount of water will be needed than if it is gravelly or sandy and where a large quantity of the water may drain away."—FAIJA.

An excess of water in concrete mixing is an error, for then the water affects too much the grains of cement which should be merely brought to a gelatinous, separates the particles of cement and sand, **delays the hardening and drying of the cement and makes it more porous than it would otherwise be.**

XVI

"The suitability of Portland cement concrete, especially for house-building purposes, is so generally acknowledged that it is almost superfluous to describe or enumerate its many advantages over brick and stone for ordinary erections:

"First—Increased strength. Second—Reduced cost. Third—Resistance to atmospheric influences and from its comparative non-absorbence the capacity of resisting damp, whether internal or external.

"Fourth—Durability from its ultimately becoming crystalized, and instead of deteriorating with age becomes harder and stronger.

"Fifth—Flat floors and roofs, plat-band arches with inexpensive covering in case of roofs.

"Sixth—Possibility of adopting non-skilled labor in the preparation of the concrete and placing it in position.

"Seventh—No delay need arise in drying, as in case of green brickwork, as the cement concrete possesses the property of exuding the water of mixture as soon as it sets.

"Eighth—Facilities of warming and ventilating floors of concrete.

"Ninth—Cheap form of roofs may be made of concrete. It is of primary importance in all constructions that the cement should be of the best quality and its mixture or combination with the gravel or shingle or other aggregate should be carefully performed.

"A non-absorbent and wall or floor has long been considered a desideratum, and the most enlightened sanitary reformers have always regarded a house imperfect wherein that quality is wanting.

"In England the common brick absorbs as much as a pint or pound of water, supposing the external walls of an ordinary cottage to be one brick thick and to consist of 12,000 bricks, they will be capable of holding 1,500 gallons or six and one-half tons of water when saturated. To evaporate this amount of water would require nearly a ton of coal well applied.

"The softer and more workable stones are of various degrees of absorbency, are often more retentive of moisture than common brick. When water presents itself in any part of such material as brick or stone, it readily diffuses itself by the power of capillary attraction by which it ascends thirty-two feet from the foundations.

"Any building constructed of good Portland cement concrete may be accepted from its dryness soon after the concrete is set, and of proper strength—no drying out of the walls required.

"By experiments with a sample of first-class Portland cement, with which one hundred parts of cement powder was mixed with thirty-five parts water, it was found that eleven and one-half per cent. of it was retained in chemical combination with the cement to complete the final process of crystallization, proving that the amount of water rejected during setting processes was about two-thirds of that used in rendering the cement powder plastic; showing that a very small amount of latent moisture is retained in the hardened mass and the quantity which it may afterwards be capable of absorbing will depend on the porosity of the concrete, the extent of which will indicate its capillary capacity.

"An unusually porous aggregate will be beneficially influenced by being mixed with Portland cement as the silicates and illuminates will, when in a fluid state, fill its pores, rendering it less liable to absorb water.

"By the present imperfect system of mortar making it is usual to mix about equal volumes of cement and water, as we find by experience that only one-third of the water remains permanently fixed in the hardened cement or concrete, it follows that two-thirds of the water is evaporated, leaving its previously occupied space void.

"The result is consequently on the fact of Portland cement possessing the valuable property of reclaiming its normal shape, notwithstanding the ejection of the water of plasticity. The light weight cements take more water than the heavy ones, and of course when thoroughly dried display greater porosity of texture, **so that it is an advantage** when a minimum quantity of water can be used with Portland cement concrete."—Reid.

XVII

"The proportion of sand to make first-class mortar is usually three of sand to one of Portland cement, but for ordinary purposes the proportion may be increased to eight of sand or gravel for mortar or concrete. Indeed, large engineering works are now being executed of concrete of these proportions."—Reid.

XVIII

Excess of Lime in Portland Cement—"From an excess of carbonate of lime in addition to disintegration of mortar, distortion of the work takes place from the mechanical force exerted by the imperfectly slaked lime."—Reid.

None but the best brands of cement should be used to insure good work.

XIX

"Hardening or ultimate induration in the process which follows the setting and continues for thousands of years, provided the necessary conditions have been duly observed in the preparation of the mortar, otherwise the mass soon gives indications of decay, and in such cases produces a mortar or concrete of dangerous quality, which age, instead of improving, deteriorates.

"The setting and hardening of Portland cement mortar may be practically considered as a combined chemical and mechanical process, and the degree of perfection attained is regulated by the quiescent value of the mixture.

"Unless the mass remains undisturbed, the natural cohesive and adhesive forces are unable to exert their beneficial influence and the perfect crystallization is consequently impaired."—Reid.

XX

Portland Cement Expands and Contracts—"Portland cement expands and contracts in setting and hardening. For instance, the walls of New Victoria Docks, the vertical cracks most certainly indicate that a contraction has taken place in the mass since it was laid. In the same way, a large courtyard or open space, laid in situ with concrete, will show cracks more or less across its width, which is to be attributed to the contraction of the mass. When laying a concrete pavement in any large space, such as a court-way or foot-way, it is advisable to lay it in sections to avoid cracking."—Faija.

XXI

"The sun's rays, drying winds and draughts should be kept from the concrete until it is set.

"For practical purposes any natural expansion or contraction of the sand, gravel or stone may be disregarded hence it is the cement and the mixing and setting operations, that alone may be taken as creating any variations i the size of the mass causing cracks and fissures. It is, therefore, obvious that the greater the ratio of the quantity o sand, gravel or stone to Portland Cement, the less expansion and contraction. ***All Portland Cement contrac when drying, and expand upon being put in water.***"—NEWMAN.

XXII

"Cracks may be prevented in a measure by imbedding or incorporating in the work as it progresses, clamps wire and the like.

"Concrete is liable to crack from expansion and contraction, also from unequal settlement."—GILMORE.

XXIII

"Freshly made Portland Cement expands more than that that has been air slaked."—NEWMAN.

XXIV

Mixtures—"It has been proved by numerous experiments of Mr. Calson that a mixture of 6 parts sand to 1 par Portland Cement produces a mortar far superior to any that can be made out of lime and at slightly less expense.

At the Chatham Dock Yard Works ordinary building mortar was abandoned and in its place was used a mixtur of 1 part Portland Cement to 7 parts coarse, clean, sharp sand, and one part foundry sand, containing 10 per cent. o loam or about 1½ per cent. in the mortars for use.

Coignet Artificial Stone or Concrete has been extensively used in France for 25 years, the proportions generally used are:

500 parts Sand; 100 parts Lime; 25 to 50 parts slow setting Portland Cement.

This material has been used with success in France for all kinds of work—bridges, viaducts, aqueducts o considerable span.

No advantage is gained by using a mixture of Lime and Cement. A Cement Concrete is to be preferred to one of lime and cement."—NEWMAN.

XXV

The Use of Lime with Portland Cement Concrete—When the volume of the sand exceeds 5, that of the cement loosely measured, there is an advantage in increasing the volume of the matrix at the expense of its strength by adding common lime powder within the limits of 8-10 the volume of cement.

Common lime powder freshly slaked by sprinkling, may be added to the matrix of Portland Cement in the preparation of 1-4 or 1-5 of the volume of the cement without seriously impairing its strength and with a great improvement of the texture of the beton.

When large doses of sand are used the imperviousness to water of the concrete, and also its strength, is increased by adding common lime powder in proportion not greater than 8-10 of the cement in volume. It is of greater importance that the incorporation of the lime with the cement should be thorough in order to secure a perfectly homogeneous mixture. This can be obtained by titurating the two together into a thick adhesive paste before the sand is added.

The following proportions may be relied upon to give concrete of good average quality, proportions by measure.

Portland Cement,	1	1	1	1	1
Coarse and Fine Sand,	5	6	6½	7	7½
Common Lime,	3-10	4-10	½	¾	8-10

—GILMORE.

XXVI

Aggregates and Sand—Rocks of every geological formation are more or less adapted for concrete purposes When any chance is possible a preference should be given to those rocks possessing an average amount of porosity over those of a harder texture, and deficient in the more valuable properties.

Foundry slag finely ground has been mixed with hydraulic limes with advantage.

In selection of materials for aggregates, it is necessary to examine their power of capillary attraction so as to guard against the danger of employing one too porous in character. In the absence of such precautions a material might be employed so spongy as to rob the cement of its water of hydration, and thereby prevent its obtaining a proper degree of induration.

So far as the nature and proportion of the aggregates are concerned, a rough and fairly uneven aggregate is desired, so proportioned with cement mortar that a solid concrete may be had without any spaces left between the aggregates, and at the same time without an excess of mortar. If a volume of cement mortar ***be used slightly in excess of that of the interstices of the aggregate,*** there will be if the materials are properly incorporated, sufficient cement to completely encircle and cover each particle of the aggregates.—NEWMAN.

A simple method of ascertaining the volume of interstices of quantities of small pieces of rock or stone chips to be used in concrete is as follows: Tightly fill a water-tight measure of known cubical contents with broken stone, and pour in as much water as it will hold, the water having been previously measured, the volume of water required is the cubical contents of the voids between the stones to be filled with cement mortar in the concrete. This cement mortar bears the same relation to the stone chips, as mortar does to laid up brickwork.

To ascertain the quantity of cement mortar required to fill the voids in the stone, I made the following experiments:

FIRST EXPERIMENT

Three cubic feet or 5,184 cubic inches of granite chips that had passed through a 1-inch square Mesh, measuring $\frac{7}{16}$ inch diagonally, required 2,088 inches of water to wet surfaces and fill voids of the stone, which is equal to one volume of cement mortar to $2\frac{48}{100}$ of stone.

SECOND EXPERIMENT

The same quantity of stone chips that had passed through a $1\frac{1}{2}$ inch Mesh, measuring $2\frac{1}{8}$ inches diagonally, required 2,188 cubic inches of water, is equal to one volume of cement mortar, to $2\frac{37}{100}$ of stone.

THIRD EXPERIMENT

The same quantity of stone chips that had passed through a 2-inch Mesh, measuring $2\frac{3}{4}$ inches diagonally, requires 2,196 cubic inches of water, equal to one volume of cement mortar to $2\frac{36}{100}$ of stone.

FOURTH EXPERIMENT

The same quantity of stone chips that had passed through a $2\frac{1}{2}$ inch Mesh, measuring $3\frac{1}{2}$ inches diagonally, required 2,214 cubic inches of water, is equal to one volume of cement mortar to $2\frac{34}{100}$ of stone.

The result of these experiments would show, if the cement mortar could be perfectly amalgamated with the stone, the proportions would be, 1 cement mortar to $2\frac{4}{10}$ of stone.

The Method of Ascertaining the Quantity of Cement required to make Mortar, and of suitable consistency to fill the interstices of the before mentioned granite chips. Fill completely the measure in the proportion of 7 parts gravel, the largest that will pass through a 3-16 inch mesh to 1 part sand, then pour in as much water as the measure will contain, the water having been previously measured, this will give the net cubical contents of cement required to coat the surfaces and fill the interstices or voids of the gravel and sand, which resulted as follows.

FIFTH EXPERIMENT

To Ascertain Proportions for Mortar—Three cubic feet or 5,184 cubic inches of gravel and sand in the proportions described, took 1,116 cubic inches of water. If $12\frac{1}{2}$ per cent. of cement be added for imperfect amalgamation, we have

$$\begin{array}{ll} \text{In.} & 1{,}116 \\ \frac{1}{8} & \underline{140} \\ & 1{,}256 \div 5{,}184 = 4\frac{1}{4}. \end{array}$$

Therefore we have 1 volume of cement to say 4 volumes of fine gravel, etc., for mortar.

The cement mortar required to fill the interstices, voids or vacuities between the pieces of stone aggregates in the concrete body, bears the same cementitious value and relation to the stones as mortar does to laid up brick work, or the mortar between the blocks of stone in a stone wall; therefore, the pieces of stone in the concrete body do not deteriorate the strength of the concrete, were it possible to get it evenly throughout the concrete body, but as this is not possible, I would recommend for the foundations for buildings, forming the cellar floor, plate 4, to be

1 Volume of best Portland cement; 3 volumes of Gravel = 4 volumes cement mortar; to cement, 6 volumes of broken stone that will pass through a 3-inch ring, making

1 Cement	Or One to Nine.
3 Gravel	
6 Broken Stone . . .	

The irregular surfaces of the broken stone or stone chips in a measure interlock each other when compacted with iron rammers; the elevated portions of one surface is pressed into the declivities of the adjoining piece, and through the intermediatory cement mortar are held in their interlocked positions en masse, and offer greater resistance to sliding from their positions past each other when subjected to a horizontal force, than the plain surfaces of the bricks in laid up brickwork.

P. H. JACKSON

THE CORROSIVE ACTION OF CEMENTS UPON METALS

The late Mr. J. C. Trautwine, Civil Engineer, published a brief memorandum, giving the result of some experiments which he had made to determine the corrosive action of hydraulic cements upon metal embedded in them. The cements used were English, Portland, and Louisville; in addition to which he tried Plaster of Paris pure, and also mixed with equal measures of the cements. All were of the consistency of common mortar; and all were kept in an upper room during ten years, unexposed to moisture other than that of the indoor atmosphere. The metals were partly embedded in the pastes, and partly projected from them. They consisted of cut iron nails, some of which were galvanized; smooth iron wire nails; brass in both sheet and wire; zinc in sheet; copper wire and solid cylinders of lead ⅜-inch diameter. The result at the end of ten years was that all the metals in both the pure cements were absolutely unchanged; and this was also the case with the Plaster of Paris, with the exception of the ungalvanized nails, which had become covered with a thin coating of rust, as were also those in the mixtures of plaster and cement but to a less degree. Mr. Trautwine concludes from his experiments that if dampness be excluded, both cement and lime mortar will protect from injury all the metals employed in ordinary constructions for an indefinite time.

To Make a Cistern Hold Water so it does not percolate through the walls and bottom, cement it with a cement made by mixing silicate of soda solution to a paste with quick-lime.—SCIENTIFIC AMERICAN.

Highton's Mode of Hardening Artificial Stone, *patented in England in 1868,* is as follows: If only the parts near the surface require to be hardened, make two or three applications upon the surface of silicate of soda of ordinary commercial strength. If it is required to be hardened more thoroughly, the solution should be diluted and a greater number of applications and saturated for a longer time. The lime in the Portland Cement takes up the silica from the solution. After it has become of the requisite hardness, wash it to free it from the small quantity of soluble silicate adhering to it.

Also artificial stone and natural stone may be hardened by applying successively to the surface, first, two or three applications of diluted silicate of soda, then drenched with a hot solution of chloride of calcium, which mutually decompose each other, depositing an insoluble substance in the manner as follows:

The silicate of soda and chloride of calcium forms in the pores of the stone a hard insoluble cementing substance by the mutual decomposition of the two chemical compounds in solution. When the two become mixed they form almost instantaneously by mutual or double decomposition the silicate of lime, and the chloride of sodium (common salt). The increased strength, hardness and durability depend upon the silicate of lime which fills the pores, and binds the particles solidly.

The process of making silicate of soda or flint soap is by boiling or dissolving flints in a strong solution of caustic soda under pressure.

Fill Cracks in Stoves with Soluble Glass mixed with Ashes—This will adhere to bricks without crumbling. —Scientific American.

Fire-Bricks Ground with Silicate of Soda make a good fire resisting cement.—Scientific American.

From General Gilmore's Work on Artificial Stone of 1871— Mr. F. Ransome of England's process of hardening and water-proofing of stone, brick, stucco and artificial stone. First, wash the stone thoroughly with a solution of silicate of soda, and soft or rain water, if convenient. If the material be of a very absorbent character, about an equal quantity of water will be found sufficient; but, if of a close or dense texture, about two parts water; or in some cases, even three parts should be mixed with one part silicate of soda. The prepared silicate, diluted as above, should be applied freely, but evenly, by a brush, to the surface of the stone, etc., and when properly absorbed the operation should be repeated until the stone, etc., is thoroughly charged; but care must be taken not to allow an excess of silicate to remain upon the face to dry. After a day or two when the silicate has become perfectly dry, prepared chloride of calcium should be applied freely (but brushed on lightly), so as to absorb with the silicate in the structure of the stone. This will fill up the pores of the material and firmly aggregate and cement the particles making it thoroughly water-proof.

English Patent, No. 52, 1873—Greater strength is imparted to Portland Cement or Concrete by using 2 per cent. more or less of blood. Instead of mixing the blood with the whole of the concrete it will be found more economical to use it in the top strata where it requires to be hard.

English Patent, No. 220, 1862—For preserving and hardening stone or other materials, I take dry caustic Baryta or Strontia, flake it in water so as to make it into a paste with such proportions of water as the temperature is capable of absorbing. Prefer to apply the solution to the stone, at near the boiling point.

To Strengthen Portland Cement—In Nystrom's Mechanics, page 474. Some iron filings in a very weak solution of salamonic mixed with Portland cement increases its strength to double or more.

From Prof. H. Faija's Work on Portland Cement to Users, page 202, nearly all Portland cement will give some signs of blowing if used too fresh, or has not had sufficient time to slack, or, as it is called, purge itself. It is always unsafe to use Portland cement too fresh. For this reason, all large users of cement, where possible, lay the cement out in thin layers on a dry floor and turn it over several times before using it. By this means it is effectively purged and any free lime slaked.

English Patent, No. 3,049, 1882, Portland cement mixed with suitable hard material, such as crushed granite or other stone, sand, slag, metal or other material.

Mix in a dry state. To the Portland cement and aggregates apply artificially heated water and the air is removed. This hardens it; then put it in a bath of silicate of soda and the stone becomes silicated throughout.

J. H. Bryant's English Patent, No. 15,014, 1884, Improved Artificial Stone that is moisture and fire proof, and is suitable for paving and flooring purposes, and when made into building blocks may be used for retaining and other walls. The proportions preferred to be employed are: 15 parts Portland cement; 40 parts crushed iron slag that will pass ½-inch mesh; 15 parts crushed granite that will pass through a ¼-inch mesh; 10 parts silicate of soda; 20 parts water; 100.

The 15 parts granite and 40 iron slag, and 15 parts cement are thoroughly mixed together in a dry state, and the requisite quantity of silicate of soda is dissolved in water, and the solution is then applied to the heap of dry materials from a rose watering-pot, on the whole mass, and is turned over three or more times as in making concrete. The mass may be laid in situ, or made into slabs or blocks, in moulds. Should not be allowed to set before being used.

The Portland cement is used as a binding material, and the granite to give it body, the iron slag to give it hardness and durability, as well as fire-proof quality of the material; while silicate of soda accelerates drying and increases the hardness and durability of the stone.

GRANO-METALLIC STONE

The grano-metallic stone, the invention of Mr. J. H. Bryant, *of London* (the patent before referred to), *is composed of blast furnace slag and granite, which are crushed, chemically treated, dried and mixed with Portland cement. For use these ingredients are brought to a pasty consistency with an alkaline solution* (*Silicate of Soda*) *and laid. It* possesses the important property of always having a rough surface, which is due to the *atoms of the vitreous slag* always presenting *themselves just above the other ingredients,* which are more *readily worn. This stone has undergone a special trial in one of the metropolitan gas works, where a section was laid at the request of the engineer. It was there successfully subjected to tests which natural and artificial stones have,* it is stated, *been unable to withstand. It is found to stand not only the wear and tear of heavy horse* and van traffic, but the *sudden and extreme alternations* of temperature incident to the *slaking of coke upon it.* Valuable as this material has *proved itself for paving* and road-making purposes, however, *it has now been proved* to possess the additional *important feature* of being highly *refractory.*

A cement kiln lined with this stone has stood a number of burnings without any repairs having to be done. Even where the lining happened to be torn away by a portion of adhering clinker, there is not the least sign of the stone having been injuriously acted upon by the heat. This is certainly a most crucial test, and the satisfactory manner in which the stone has passed through it stamps it at once as an absolutely fire-proof material, and, therefore, of special value for constructive purposes—IRON.

Thaddeus Hyatt's United States Patent, 1878, relates to making Portland cement and concrete fire-proof. Consists in the employment of Portland cement for fire-proof construction by mixing 10 or 12 per cent of sulphur, or pyrites, or other compounds containing sulphur with cement, to make it refractory and capable of resisting the destructive effects of cold water thrown upon the concrete in a red hot or heated state, the trials recited in this book were of this composition.

The writer is sole licensee.

HARDENING CONCRETE.

In a paper read before the South-end Mechanics' Institute, London, Mr. Henry Faija described his method patented in England of quickening the induration of concrete blocks. The concrete is made and rammed into the moulds in the usual manner, after which the moulds are placed in a chamber in which a moist heat of about 100° Fahr. is maintained. This greatly increases the crystallization or setting of the cement, and allows the object to be removed from the mould in a few hours. The concrete is then placed in a bath of 110° Fahr. composed of one part Silicate of Soda and twelve parts water. The solution penetrates to the center of the block, which is thus hardened throughout instead of merely on the surface as in the usual process. In three or four days the blocks will have attained the strength of *ordinary cement* three or four months old. The strength of cement referred to is much greater than the concrete mixture.—SCIENTIFIC AMERICAN.

THE WHISTLE

A True Story---Written by Benjamin Franklin to His Nephew, in 1784.

When I was a child, at seven years old, my friends, on a holiday, filled my pockets with coppers. I went irectly to a shop where they sold toys for children; and, being charmed with the sound of a *whistle*, that I met by he way in the hands of another boy, I voluntarily offered him all my money for one. I then came home, and went vhistling all over the house, much pleased with my *whistle*, but disturbing all the family. My brothers, and sisters, nd cousins, understanding the bargain I had made, told me I had given four times as much for it as it was worth. This put me in mind what good things I might have bought with the rest of the money; and they laughed at me so nuch for my folly, that I cried with vexation; and the reflection gave me more chagrin than the *whistle* gave me pleasure.

This, however, was afterwards of use to me, the impression continuing on my mind; so that often, when I was empted to buy some unnecessary thing, I said to myself, *Don't give too much for the whistle;* and so I saved my noney.

As I grew up, came into the world, and observed the actions of men, I thought I met with many, very many, vho *gave too much for the whistle.*

When I saw any one too ambitious of court favors, sacrificing his time in attendance on levees, his repose, his liberty, his virtue, and perhaps his friends, to attain it, I have said to myself, *This man gives too much for his whistle.*

When I saw another fond of popularity, constantly employing himself in political bustles, neglecting his own affairs, and ruining them by that neglect; *He pays indeed*, says I, *too much for his whistle.*

If I knew a miser, who gave up every kind of comfortable living, all the pleasure of doing good to others, all the esteem of his fellow-citizens, and the joys of benevolent friendship, for the sake of accumulating wealth; *Poor man*, says I, *you do indeed pay too much for your whistle.*

When I meet a man of pleasure, sacrificing every laudable improvement of the mind, or of his fortune, to mere corporeal sensations; *Mistaken man*, says I, *you are providing pain for yourself instead of pleasure; you give too much for your whistle.*

If I see one fond of fine clothes, fine furniture, fine equipages, all above his fortune, for which he contracts debts, and ends his career in prison; *Alas*, says I, *he has paid dear*, *very dear*, *for his whistle.*

When I see a beautiful, sweet-tempered girl, married to an ill-natured brute of a husband; *What a pity it is*, says I, *that she has paid so much for a whistle.*

In short, I conceived that great part of the miseries of mankind were brought upon them by the false estimates they had made of the value of things, and by their giving too much for their *whistles.*

Emerson says that concentration is the secret of success, and Benjamin Franklin when a poor boy proved the truth of the remark. He went to London and applied for work at a printing office. The printer, doubting whether an American could do anything well, asked Franklin if he could really set type. For reply the boy stepped to one of the cases and set up the forty-sixth verse in the first chapter of John's gospel. It was done so quickly and so accurately and conveyed such a delicate reproof that he obtained employment at once and was rapidly promoted.

The young person nowadays who knows how to do one thing thoroughly well, who is determined to do it better, if possible, than anybody else, is more likely to succeed than one who knows more but excels in nothing. Mr. Vanderbilt pays his cook a salary of ten thousand dollars a year because he understands the art of cooking to perfection. As Mr. Burdette says in his funny way, "If Monsieur Sauceagravi could cook tolerably well, and shoot a little, and speak three languages tolerably well, and keep books fairly, and could telegraph a little," and so on with a dozen other professions, "he would'nt get ten thousand a year for it."

Plate 4.

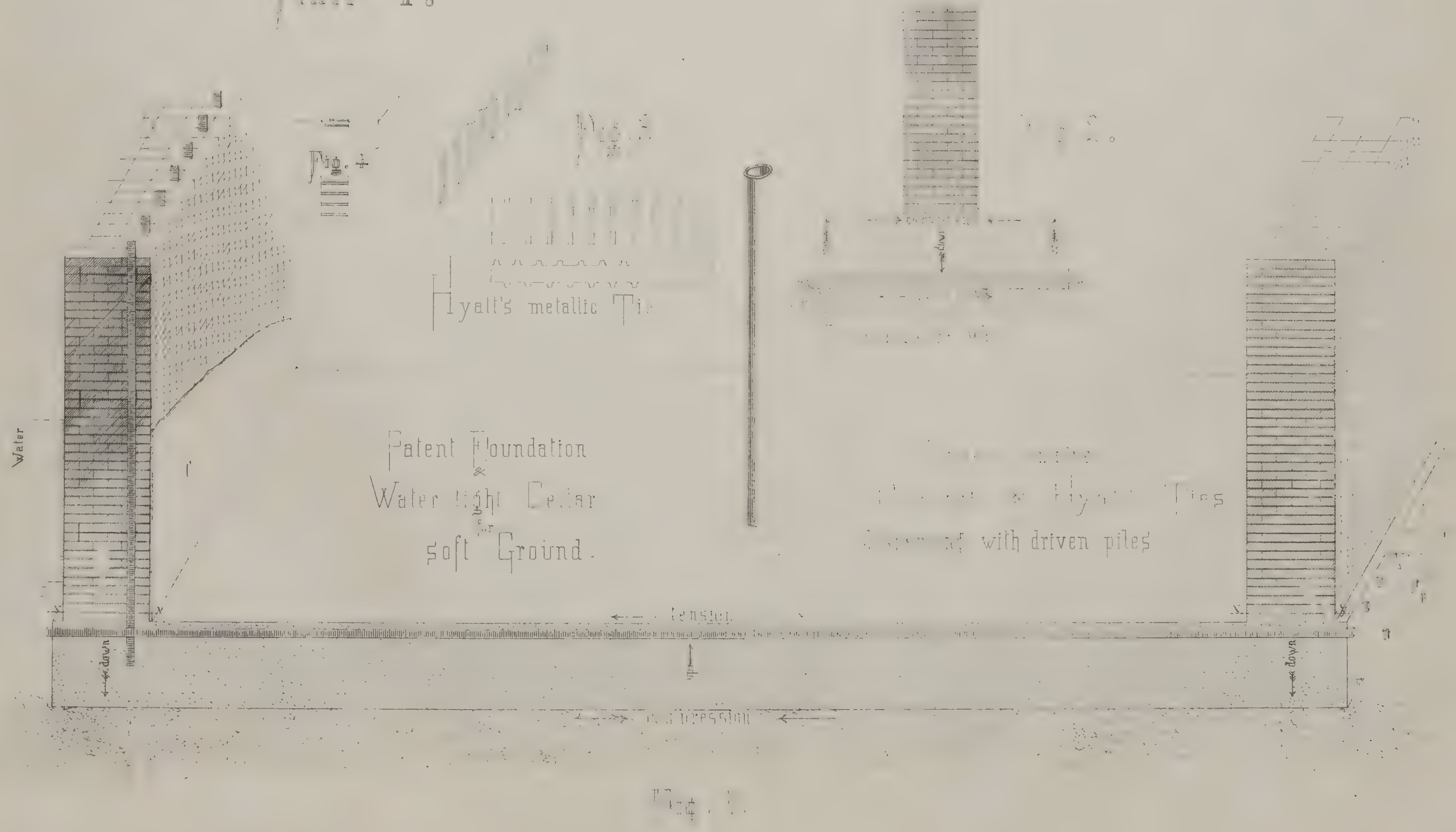


Fig. 4
Hyatt's metallic Ti
Patent Foundation
&
Water tight Cellar
for
soft Ground.
with driven piles
Water
tension
down
down

DESCRIPTION OF PLATE 4.

Figure 1, plate 4, illustrates a water-tight concrete bottom or foundation of a building, resting upon soft ground, doing away with driven piles.

The concrete bottom being the size of the building from its extent resists settlement. It also forms with the water-tight walls a water-tight basement.

The basement may be of any depth consistent with the resistance of the earth beneath it. By this construction valuable business property may be employed in basement use, which would otherwise probably be of little value.

The walls at each end upon the concrete bottom, as shown in figure 1, press down the part on which they rest as indicated by the arrows beneath them. The part between the walls, being without this weight, is subjected to an upward pressure of the resisting earth beneath it to balance the weight of the walls, this tends to camber the concrete body between the walls, the top surface of the concrete becomes convex and is subjected to tensile strain, and the bottom surface becomes concave and is subjected to compressive force.

The employment of the concrete bottom is on the beam principle, with the difference that the pressure and consequent transverse strain on a beam is from the load on its top is in a downward direction, while the pressure from the resisting earth beneath the concrete bottom is in an upward direction.

The method of computing the strength of this concrete bottom as a beam heretofore given, is first to theoretically divide the concrete bottom in sections along the length of the wall, each section having a certain number of Hyatt ties.

Suppose the building walls are each 100 feet long, and the distance between walls 25 feet with the ties extending across, by dividing the 100 feet into 20 sections will give 5 ft. for each section, which is equal to a concrete beam 5 feet wide, and the distance between the walls of 25 ft. equals a beam 5 ft. wide and of 25 ft. span. Assuming the distance from the top of Hyatt's ties resisting tensile strain, down to the bottom of the Hyatt's ties resisting compressive force to be 20 inches, we have a concrete beam as follows: 5 feet wide (*compute the sectional area of ties to be tensilely employed in the 5 feet*) x by 20 inches deep x by constant and divide by 25 feet span in inches, gives the breaking weight, for further particulars, see calculations before given for combined arches and sidewalks.

The concrete mixture may be of 1 volume best Portland cement to 3½ volumes of gravel, and 5 volumes of broken rock and ⅝ of a volume of lime may be added—to be thoroughly mixed and all else as before described for artificial stone sidewalks and arches combined.

The resistance to compression of concrete of this mixture is to be computed only at 1,200 pounds per square inch, instead of 1,800 pounds of the mixture previously given for artificial stone arches and sidewalks combined. Whatever may be, if any, the deficiency in compressive strength of the concrete computed at 1,200 pounds per square inch, is to be made up in Hyatt ties in the part employed to resist compressive force.

After this adjustment of the compressive strength, which must be fully up to and may be in excess of requirement to counteract the tensile strain of the ties opposite, then the computation as to strength of the construction is to be made based upon the tensile strength of the ties, etc., as heretofore given.

The manipulation and treatment of the concrete mixture, and modus operandi throughout is to be as before given.

The walls are shown to be of brick, or may be of concrete, with the ties built in them. If of brick, as shown, it is best to have the bricks recessed as in figure 4, and the Hyatt ties to be cemented to the bricks with Portland cement.

It will be observed that the bottom of the Hyatt ties built in the wall to resist tensile strain, extends down into the concrete bottom, this is a necessity; and the upper part of the wall should press against the joists, which should be braced so as to employ the strength of several of them to resist the inward pressure of the wall. These two are bearings—resistants to the outward pressure against the wall.

The inside of the walls, if of brick, to be plastered with a very thick coat of Portland cement.

The brick walls to be well laid up in Portland cement mortar. It is important that the first row of bricks of the walls be bedded in the top of the concrete when the concrete bottom is made, then the next layer of bricks, and so on up becomes firmly united to the bottom; cement mortar does not unite well with a hard concrete or artificial stone surface unless the outer surface is cut off. Figure 3 are views of a Hyatt tie with projections formed upon its sides of the kind before described. The computation as to the transverse resistance of the walls may be made by the same formula as that for concrete, with allowance for the difference in strength in resistance to compression of brickwork compared to concrete.

SKETCH OF DANIEL WEBSTER

A long time ago, not quite a century, however, upon a New England farm a mischievous woodchuck was caught after much time and patience had been expended. It was the intention of the farmer's sons to put the animal to death, but the younger boy's heart was touched with pity; he begged that the captive might go free. His brother objecting the case was carried to the father.

"Well, my boys," says the farmer, "there is the prisoner; you shall be the counsel and plead the case for and against his life and liberty, while I will be the judge."

The older boy, whose name was Ezekiel, opened the case. He urged the mischievous nature of the animal, cited the great harm already done, said that much time and strength had been spent in securing him, and now, if he were set free, he would only renew his depredations. He also urged that it would be more difficult to catch him again, for he would profit by this experience and be more cunning in the future. It was a long and practical argument, and the proud father was apparently quite affected by it. Then came the younger boy's turn. He pleaded the right of anything which God had made to life. He said that God furnished men with food and all they needed; could they not spare this little creature who was not destructive, and who had as much right to his share of God's bounty as they had; could they not spare to him the little food necessary to existence? Should they in selfishness and cold-heartedness take the life which they could not restore again and which God had given?

During this appeal tears started to the farmer's eyes, and while the boy was in the midst of his argument, not thinking that he had won the case, the judge started from his chair, and dashing the tears away exclaimed:

"Zeke! Zeke! You let that woodchuck go!"

This incident I have briefly written out for you is told of the early life of the man who forty years later made his celebrated speech in the Senate Chamber in defense of the Constitution, which ended with these memorable words: "Liberty and union now and forever, one and inseparable!"

Daniel Webster, the orator and statesman, was born in Salisbury, N. H. The house in which he first saw the light is, I think, still standing, though not as it was originally; some years ago it became the wing or kitchen part of a new house. The farm was rugged and not very fertile; it is said that granite rocks visible in every direction gave an air of barrenness to the scene. Among "wild bleak hills and rough pastures" his boyhood was spent. His advantages of education were limited. The family library consisted of "a copy of Watts' Hymns, a cheap pamphlet copy of Pope's Essay on Man, and the Bible, from which he learned to read, and an occasional almanac."

He struggled with poverty through his college days, and after graduating at Dartmouth went to Boston to study law. He is described as "raw, awkward, shabby in dress, his rough trousers ceasing a long distance above his feet." After much discouragement he was entered in a law office as a student. He was admitted to the bar in 1805, and in 1808 he married Miss Grace Fletcher. A pretty story is told of his engagement. One day he was assisting the young lady in disentangling a skein of silk; suddenly he said: "Grace, cannot you help me tie a knot that will never untie?" "I don't know, but I can try," she said.

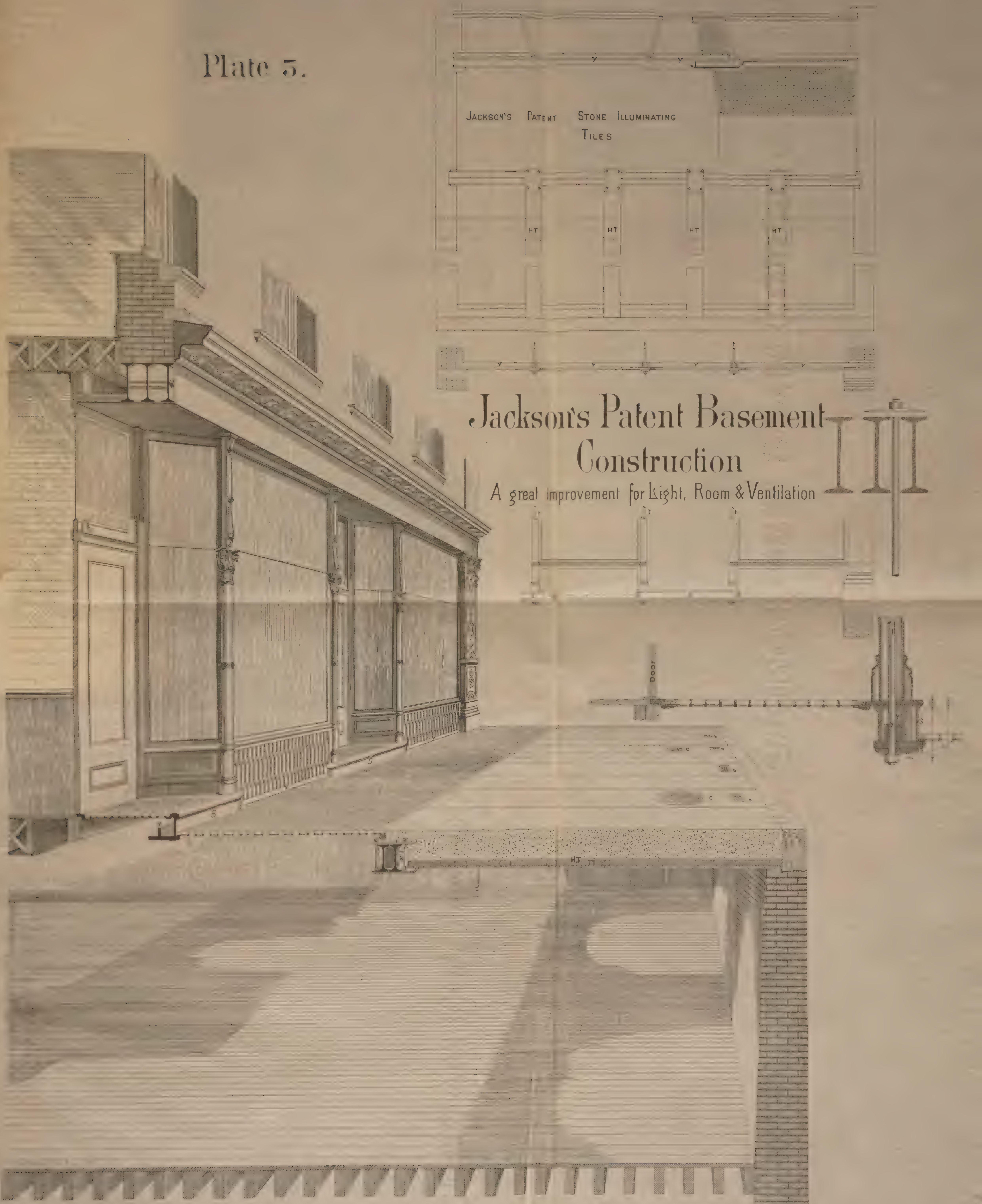
And they tied the knot, and the writer who tells the story, says, "Though eighty years have sped by, it lies before me to-day, time-colored it is true, but nevertheless still untied."

Mr. Webster was a member of Congress eight years, was in the United States Senate eighteen years and a cabinet officer five years. It is related of him that he tore up his college diploma, saying, "My industry may make me a great man, but this parchment cannot." A classmate says he was remarkable in college for three things: Steady habits of life, close application to study and the ability to mind his own business. Is it any wonder that he became a great man?

There is much in the life and character of Daniel Webster worthy of study, and many incidents are related which illustrate his greatness. One of the best things on record is this: At a dinner party given in his honor some one asked him the question, "Mr. Webster, what is the most important thought that ever occupied your mind?" To this he replied, "The most important thought that ever occupied my mind was the thought of my individual responsibility to God."

Mr. Webster died in 1852. Thousands came to attend the funeral, and amid the sorrowing throng they laid him away in the family tomb at Marshfield. Thirty years more passed and 1882 had come. It was then one hundred years since his birth, and again thousands upon thousands came to honor the memory of this son of New England. Men high in office—even the President of the United States—military men, scholars, judges, lawyers and ministers, men and women of the city and from the hillsides and from the valleys came to the sad, solemn celebration. And a long procession moved amid the tolling of bells, the booming of cannon and the low, solemn dirge played by military bands.—PANSY.

Plate 5.



Jackson's Patent Stone Illuminating Tiles
HT
Jackson's Patent Basement Construction
A great improvement for Light, Room & Ventilation
Door

DESCRIPTION OF PLATE 5

Plate 5 illustrates a first story front, with large show windows adapted to retail business, with a basement beneath without piers nearer than about every twenty-four feet; by their omission the basement extends out from under the building unobstructed under the sidewalk to the outer wall under the curbstone, thereby making it one large room; and the daylight from the sidewalk lights is free to light back towards the rear of the deep basement, instead of in the ordinary construction where the large basement piers are equal to a semi-wall, dividing the basement from the space under the sidewalk, and they also shut off fully one-half the light from the sidewalk lights to light towards the rear of the basement.

Plate 1, in the front of the book, is a store front better adapted to wholesale business, while Plate 5 is a store front with large windows for the exhibition of goods at retail.

The reading matter opposite to and pertaining to Plate 1 will elaborate the merits of this construction as well as that of Plate 1.

Our stone illuminating sidewalk lights have no iron frames, but are of glass in place of iron; the whole of the upper surface is of stone and glass and has about seventeen per cent. more glass surface than when iron frames surround the illuminating tiles, besides there is no iron on the top surface to rust.

They are glazed alternately with refracting lenses, when so ordered, which emits light from the lower side of the lens as shown in Figure 4, Plate 1.

An illuminating stoop or stoops may be constructed in entrances as shown in Plate 3, Figure 1.

The combined sidewalk and arches are made as described and shown in Plate 2, or may be as in Plate 1, or otherwise.

DESCRIPTION OF CONSTRUCTION

The brick wall above the first story front is supported by a girder made of either 15 inch, 20 inch or 24 inch steel beams, as required for strength, which are more reliable for strength, and of less cost than a made-up wrought-iron girder. But any iron girder may be used for this purpose. In the back of the book a Franklin girder is shown, which is adapted to Plate 5 and Plate 1 as well.

Iron suspension rods, t, extend down from the girder of steel beams through the sash columns, which columns may be of cast iron as shown in the drawing, or of boiler tubes cut out for the sash, and with cast-iron ornaments upon them; or even of wood.

These rods, t, extend down through the doorsill and through the iron beam, y, and have washer plates and nuts on the bottom.

At the top of sheet, Plate 5, will be seen a plan of the bottom iron beam, y, extending the width of the front, its ends resting on the basement piers, and at certain distances apart is sustained by the tie rods, t, extending down from the girder over the first story front. The iron beam, y, not only sustains the parts between the rods but secures all the parts resting upon it in their relative positions in every direction.

In the middle of the sheet, and to the right, will be seen a cross section of the steel girder beams, tie rod, t, base of sash column, illuminated vestibule floor with the rod, t, passing through it and through the iron beam, y, with an iron plate washer beneath and a nut on the end of the screw bolt, t.

Riser S is shown. Refracting and plano-convex lens are shown in the illuminating tiles and the arrows indicate the direction of the rays of light from them.

In the middle of the sheet above the sidewalk is a small elevation showing the tie rods, t, t, passing down into the sash column and through the iron beam y with the screw nut on bottom.

This substantial construction may be seen in the basement under the Occidental Restaurant, No. 337 Bush St.; also a part of the basement construction at Nos. 748–752 Mission St., this city. The sash columns in the latter instance are of wood, the suspension rods t passing through them.

As there are no basement piers to rest the inner ends of the supporting arches of sidewalk, they are sustained on the vault girder K, which in this instance consists of two rolled beams. Upon them is formed the wrought-iron shoes which connect and employ both beams of the girder *equally* in support of the loads of the ends of the concrete beams of sidewalk. An illustrated sheet will be sent on application showing how the iron shoe employs both *beams equally* in support of the load of the end of the concrete beam.

Hyatt ties marked H. T. in the plate of the concrete or artificial stone combined arch and sidewalk, are the same as shown in plate 2 and described.

Iron beams may be employed instead of the ties H. T., as shown in plate 1.

If the vault girder K is of too long a span for strength for the two beams shown, three beams may be used, or if two beams are used they may have a small supporting column between the end supports.

Wrought-iron open lattice work is shown under the store windows, this with a swing sash behind, and the sash open, ventilates the basement. Open ventilators, b, are shown in sidewalk, which generally have iron pans beneath to catch the dirt and water. Ventilating hitching-posts and carriage blocks are used as well for the purpose of ventilation. See illustrations of them on second page after plate 3.

In view of the many computations made in this work, including the following safe-bearing loads of cast-iron columns and pillars, computed from Hodgkinson's formulæ by me for use during my connection with the Department of Buildings of New York city, I concluded it would be well to insert the following letter, received by me soon after my resolve to remain and reside in San Francisco.

DEPARTMENT OF BUILDINGS,
Office of Supt., No. 2 Fourth Avenue,
NEW YORK, Nov. 27, 1875.

P. H. JACKSON, ESQ.,

SIR: This is to certify that you have been, for nearly five years, Chief of the Bureau of Iron Construction; also expert in matters of iron construction for this department, embracing the City and County of New York.

Every case of building construction requires the consideration and sanction of this department, in conformity to law, before such can be erected.

The most difficult cases were under your direction for solution, and have given entire satisfaction; the testing of iron beams, girders and lintels, from the first passage of the law requiring such to be done, was under your management.

I would recommend you not only as scientific, but practical, in matters of iron construction, from your business experience, having been connected with one of the largest iron manufacturing establishments in this city for several years.

Respectfully yours,
WALTER W. ADAMS,
Superintendent of Buildings.

HOLLOW, ROUND OR RECTANGULAR CAST-IRON COLUMNS OR PILLARS

The knowledge of the strength of hollow cast-iron columns or pillars was principally obtained from experiments of over 200 examples by Mr. Eaton Hodgkinson, in the year 1840.

As deducted from these experiments it was found, that where the columns were shorter than 30 external diameters, that the weight required to break them by bending is so great that the crushing force becomes sensible, and the column yields to the combined effect of the forces. But in a column of a length exceeding 30 external diameters, although the pressure contributes to break it by crushing as well as by flexure or bending, yet the column yields from bending with a weight which is insufficient to effect it by crushing alone.

When a column is less than 8 external diameters in length its full crushing strength comes into play.

The experiments were made with columns of flat ends dressed at planes right angles to their axis.

A column has two functions, one to support the weight, and the other to resist flexure.

A pressure that produced change in the breaking of the columns was about one-fourth of that which crushed the material. Therefore, one-sixth of the breaking weight which is given in the following tables of about 2,400 examples, computed by Hodgkinson's formula, is in conformity with the generally accepted proportions of the safe employed weight to the breaking weight, when the column is at rest.

The building laws of the large cities of the United States generally require this proportion when the ends are at planes at right angles with its axis, and with level cap and base plates; the latter to be planed if not level.

If the column is to be employed in an unusual duty, as in support of a load subject to vibration from machinery in motion, or to be loaded more on the one side than the other, or the column is disproportioned in metal thickness by large swells, consoles, or other projections cast on the shaft, largely increasing its thickness in one or more parts of the shaft, and comparatively thin in other parts, its strength is impaired by unequal shrinkage. When the parts are not of equal thickness, the metal cools unequally, and is, therefore, partially strained by irregular contraction. When the projections are very large and are connected to a thin shaft, it will generally be found upon close examination, to be slightly fractured at the juncture of the unequal parts, which has partially relieved the initial strains due to counter shrinkages.

To meet cases where the column or pillar is of ordinary plain or fluted shaft, which may have the astragal, base molding, and such small projections cast upon it (it is proper to employ at the rate given in the tables), but if to be employed, as subject to vibration and other severe employments at less than one-sixth the breaking weight, reduce the safe employed load in tons given in the tables to the breaking weight by multiplying the figure given by 6. For

instance, a column whose safe employed load is 100 tons multiplied by 6 equals 600 tons breaking weight, upon this basis—it may be employed by dividing by 10, will give one-tenth its breaking weight, by dividing by 15 will give one-fifteenth its breaking weight, and so on. By this means the reader has at hand the breaking weight of any column or post computed by the Hodgkinson formula, which may be employed in any proportion.

A column with large cap and base plates cast on ends of a thin shaft should not be employed in excess of one-twelfth its breaking weight, as directly after the molten metal is poured into the mould it begins to contract in length, the cap and base plates at the ends of the column are at right angles to it, and being deeply embedded in the mould, holds to it and resists contraction during solidification from the melted state, at a time when the metal is of feeble strength; also, the end plates being comparatively larger bodies than the shaft and in a cross-direction to it, draw or aggregate to themselves in shrinking, to the injury of the thinner contracting shaft between them.

When a column or pillar is employed with the load all on one side as resting on a bracket, its strength is but one-third of that given in the tables, which is for a load squarely upon its top. The load upon the bracket, if a rectangular pillar, is mainly upon one side which is compressed, the two sides connected to the loaded side bear a small proportion of the load, and the side opposite to the loaded one will be extended, employed as a tie reversely to the loaded side and made to conform to the curvature of the pillar, caused from the unequal loading. The load in such a case is in the direction of the diagonal.

Page 350, 71st section of Mr. Hodgkinson's work on the strength of cast-iron pillars, directly refers to the employment of pillars in this way. The quotation is as follows:

" A pillar irregularly fixed so that the pressure would be in the direction of the diagonal is reduced one-third of its strength, the case being similar to that of a pillar with rounded ends, the strength of which has been shown to be only one-third of a pillar with flat ends. Therefore, to find the safe-bearing load in such a case, divide any of the safe-bearing loads given in the tables by three, which makes one-eighteenth of its breaking load with the same applied upon its top. Should the bracket be large on a comparatively thin shaft, greater latitude should be allowed as it cools and draws to itself, shrinks unequally with that of the shaft, and the metal is weak at the place of juncture of bracket with the shaft. In such a case it is best to employ not under one-twentieth of the breaking weight. The impaired strength of the shaft will lessen correspondingly as the size of the bracket is decreased.

" A long post with heavy cap and base plates cast on ends, and with a heavy bracket compared to the shaft, and loaded only on one side, in my opinion, should not be employed in excess of one-twenty-fifth of the breaking weight, computed with the load applied evenly on the top as given in the tables."

" From the preceding remarks do not let it be understood that small projections upon the shaft, as the astragal, the moulding above the plinth, and such small projections usually cast on the columns or pillars, will particularly impair its strength, as there is the difference between one-fourth of its crushing strength where derangement of the metal ceased and the employed load of one-sixth, which is a greater difference than common to cast or wrought iron beams employed at rest."

Cast-Iron Columns Safer, when Exposed to Heat, than Wrought-Iron Columns.

From Scientific American, July 25, 1885.

Some interesting and instructive experiments have been lately undertaken by Professor Bauschinger, of Munich, in reference to the safety of cast-iron columns when exposed to the action of great heat.

The professor, having arranged some cast and wrought iron columns, heavily weighted, exactly as they would be if supporting a building; had them gradually heated, first to three hundred degrees, next to six hundred degrees, and finally to red heat; then suddenly cooling them by a jet of water, just as might happen when water is applied to extinguish a fire. The experiment showed that the cast-iron columns, although they were bent by the red heat, and exhibited transverse cracks when cold water was applied, yet they supported the weight resting on them; while the wrought-iron columns were bent before arriving at the red heat, and were afterwards so much distorted by the water, that the re-straightening of themselves was out of the question. In fact, if supporting a real building, they would have utterly collapsed under the weight they had to sustain. The professor therefore concludes, as the result of his experiments, that cast-iron columns, notwithstanding cracks and bends, would continue to support the weights imposed upon them; while wrought-iron columns would not.

In experimenting on pillar stone, brick, and cement concrete, the last was found to be the best. Cement concrete pillars withstood the fierce action of the fire for periods varying from one to three hours; brick pillars, as well as those of clinkers, set in cement mortar, displayed great resistance; while natural stone, granite, limestone, and sandstone were not fire-proof.

It would, therefore, appear that of the several materials for pillars supporting weights, the best for fire-resisting purposes were the cast iron and Portland cement concrete.

Cast iron resists the enormous crushing force of 93,000 pounds per square inch, while that of wrought iron, about 36,000 pounds per square inch, or a little over one-third of cast iron. The result of the experiment is not a surprise to the writer, as cast iron, properly proportioned, is best adapted to resist compressive force, while wrought iron's adaptability is that of a tie, or equal employment in resisting tensile strain.

For fire-proof buildings, in the opinion of the writer, it would be better to double the thickness of the iron columns and girders (which are the main supports) in excess of their normal requirement, for additional strength to provide for the decimating effects of heat; they may be even quadrupled in strength in exposed places, and when they become heated to a certain temperature they will still be fully up to the required strength in sustaining the load. The increased expense should only be the additional cost of increased iron, and the cost of melting it for the columns; and the cost of the extra weight of the material and the very slight cost of workmanship of the girders.

Many of the fire-proof surroundings of columns, girders, and with partitions as well, are short, hollow sections of thin fire-brick, or like material, requiring several of them to make up the length of a column, or the height from floor to ceiling of a fireproof partition. Their meeting edges are thin, and fire-brick material, particularly where it is glazed, has not the porosity like common brick to seize and adhere strongly to the small body of cementing material at the joints, rendering these places of less resistance to strain than other parts over the length.

When severe heat attacks the exposed surface of these in most cases thin fire-brick sections they expand, and as they are confined between the rigid floor and ceiling, to conform to this expansion it must be in the weaker joints and to their injury. In addition thereto the heat is not transmitted directly to the back surface of the shell, which is comparatively cool because the dull conducting air-space intervenes, consequently the expansion and consequent curvature of the heated surface is not re-enacted by the comparatively cool back part, the expanded heated surface becomes convex over its length without its attached counterpart at the back becoming correspondingly concave; the result is the impairing or destruction of the connecting parts from unequal expansion.

Firebrick expands 1/4,250 of its length to every 100 degrees of heat.

Common brick expands 1/3,270 of its length to every 100 degrees of heat.

Granite expands 1/2,280 of its length to every 100 degrees of heat.

A high, solid brick wall when exposed to heat on the one side slowly expands on that side, and gradually through; the material being solid from its homogeneity a proportion of the heat is gradually and uniformly transmitted through to the opposite surface unexposed to heat and it expands; the heat is much more gradually absorbed through the body to the unexposed side than if an air-space intervened, which is foreign to its conductivity, and not only interrupts it but breaks it up, making the two sections of the wall partially independent of each other in expansion.

The inventor of these improved firebrick or terra cotta fireproof constructions, devised a means to attain certain valuable results to prevent the destruction by fire of iron columns and girders, and for fireproof partitions, providing the fire is not too fierce and of too long continuance; but it is not within his province to proportion the parts and execute the work; his was only the general method of accomplishing an end.

The makers of these fire-protecting sections, in order that they may be used by keeping within a certain range of expenditure in their construction and be more convenient for handling, make the parts too thin and in too short pieces, and the contractor, in his competition to obtain the contract, usually figures to put up the building in a way at the least expense, and the result is: the original intention of the inventor of what would be an excellent method, carefully and properly carried out, fails in execution, which, to the casual observer (bolstered up by its popularity as a fireproof construction) seems up to all requirements, but when subjected to the scourge of fire is found to be a sham.

TABLE

Of safe-bearing loads in tons, that hollow cast-iron columns may be employed of average uniform thickness, with their ends at planes and at right angles with the axis of the column, cap and base plates cast separately and planed. The breaking weight being six times greater. Read preceding article.

COLUMNS 8 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
4 inches.	12½	16	18½	21	22½	24	25						
5 "		25	29½	34	38	41	44	46					
6 "		35	42½	49	55	61	65½	70	74	77½	80½		
7 "			56	65	73½	81½	88½	96	101½	107½	112½	117½	125
8 "			69	81	92½	103½	113½	122½	131	139	146½	154	166
9 "			83½	98½	111½	125	138	150	161½	172	182½	191½	209
10 "			97½	115	131½	147½	163½	178	192	205½	218½	230½	253
11 "			111½	131½	151½	170½	188½	206	223	239	254½	269½	297½
12 "			126	149	171	193	214	234	254	273	291	308½	342½
13 "			140	166	191	216	239	262½	285	306½	328	348½	387½
14 "			154	182½	211	238½	265	291	316	341	365	388	432½

COLUMNS 9 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
4 inches.	11	13½	16	18½	20	21	22	23					
5 "		22½	26½	31	34	36½	39	41½	43½	44½	46	46½	
6 "		32	38½	45	50	55	59½	63½	67	70	72½	75	78½
7 "			51½	60	68	75	81½	88½	93½	99	103½	107½	115
8 "			65	76	86½	96½	106	114	122½	130	136½	143	154
9 "			79	92½	106	118½	130	141	151½	161½	171	180	196
10 "			93½	109	125	140½	155	169	182	195	206½	218½	239
11 "			106½	126	145	163	180	196½	212½	228½	242½	256½	283½
12 "			121	143½	164½	185½	206	225	243½	261½	279	296	327½
13 "			135	160	184½	208½	231	253½	275	296	316	335½	372½
14 "			149	177½	204	231	256½	281½	306	329½	352½	375	417½

COLUMNS 10 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
4 inches.	10	12½	14	16	17½	18½	19	20					
5 "		20	24	27½	30½	33½	35	37	38½	40			
6 "		29½	36	41	46	50	54	58	61	63	66	69	71
7 "			48	56	63	69½	76	81	86½	91	95	98½	105
8 "			61	71	81	90	98	106½	114	121	126½	132½	143
9 "			74½	87½	100	111½	122½	133	142½	151½	161	168½	183½
10 "			89	104	119	133½	147	160	172½	184	195½	206	226
11 "			102½	121	138½	156	171½	187½	202½	217½	231	244	269
12 "			116	137½	158½	178	197	216	233½	251	267½	283½	313½
13 "			131	154½	178	201	222½	243½	264	284	303½	322½	357½
14 "			145	171½	197½	223½	248	272	295½	318½	340½	361½	402½

COLUMNS 11 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
4 inches.	9½	11½	13½	15	16	16½	17	17½					
5 "		18½	21½	25	27½	30	31½	33½	35	36			
6 "		27	32½	37½	42	46	49½	52½	55½	58	60	61½	64½
7 "			44	51½	58½	64	70	75	79½	83½	87½	91	96½
8 "			57	66½	76	84	92	99	106	112½	118½	123½	132½
9 "			70½	82½	94	105	115	125	134	142½	151	158½	171½
10 "			84	98½	113	126½	139	151½	163½	174	185	194½	212½
11 "			97½	115	132½	148½	164	179	193½	206½	220	232½	255
12 "			111½	132	151½	171	189	206½	223½	240	256	271	299
13 "			126	149	171	193½	214	234	254	273½	291½	309	343½
14 "			140	166	191	216	239	262½	285	306½	328½	348½	387½

COLUMNS 12 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
4 inches.	8½	10	11½	12½	13½	14	15	15½					
5 "		16½	20	22½	25	26½	29	30	31	32½			
6 "		25	30	34	38½	42½	45½	48½	51	52½	55	56	58½
7 "			41	48	54	59½	65	69	73½	77½	81	83½	88½
8 "			53½	62½	71	78½	86	92½	99	104½	110	114½	123
9 "			66½	77½	88½	98½	108½	117½	126	134	141	148½	160½
10 "			80	93½	107	120	131½	143½	154	165	174½	183½	200½
11 "			93½	110	126	141½	156	170	183½	196½	209	221	242½
12 "			107½	126½	145	163½	181	197½	213½	229	244	258½	285
13 "			121	143½	165	186	206	225	244	262½	280	296½	328½
14 "			135	160	184	208½	231	253½	275	296	316	336	373
15 "			149	177	204	231	256½	281½	306	329½	352½	375	417½
16 "			163½	194	224	253½	281½	309½	336½	363½	389	414	462½

COLUMNS 13 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
4 inches.	7	8½	10	11	11½	12½	13	13½					
5 "		16½	20	22½	24	26	27½	28½	29	30			
6 "		23½	27½	31½	35½	38½	41½	44	46½	48½	50	51½	[illegible]
7 "			38½	44½	50	55	60	64	68½	71½	74	77	[illegible]
8 "			50	58½	66	73½	80	86½	92½	97½	102½	106½	[illegible]
9 "			62½	73½	83½	93½	102	110½	118½	126	132½	139	[illegible]
10 "			76	89	101½	113½	125	136	146	156	165	173½	[illegible]
11 "			89	105	120	135	148½	162	175	186½	198½	209	[illegible]
12 "			102½	121	139	156½	173	189	204	219	233½	246½	[illegible]
13 "			116½	138	158½	178½	197½	216	234	251½	268½	284	[illegible]
14 "			130½	154½	178	201	222½	244	265	285	304	323	[illegible]
15 "			144½	171½	197½	223½	248	271½	295½	318½	340½	361½	[illegible]
16 "			158½	188½	217½	246	273½	300	326½	351½	376½	401	[illegible]

COLUMNS 14 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
5 inches.		15	17½	19½	21½	22½	24	25	25½	26			
6 "		21	25½	29	32½	36	38½	41	42½	44	46	47	[illegible]
7 "			36	41½	46½	51	56	59½	63½	66	69	71½	[illegible]
8 "			47	55	62	69	75	81	86	91	95	99	[illegible]
9 "			59	69	78½	87½	96	104	111	118½	124½	130½	[illegible]
10 "			71½	84	96	107½	118½	128½	138½	147½	156	163½	[illegible]
11 "			85	100	114½	128½	141½	154	166	177½	188½	199	[illegible]
12 "			98½	116	133½	149½	165½	181	195	209	222½	235	[illegible]
13 "			112	132½	152½	171	190	207½	225	241	257½	272½	[illegible]
14 "			126	149	171½	193½	214	235	255	274	292½	311	[illegible]
15 "			140	166	191	216	239½	262½	285	307½	328½	349	[illegible]
16 "			154	182½	211	238½	265	291	316	341	365	388½	[illegible]

COLUMNS 15 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
5 inches.		13½	16	17½	19	20½	21	22	22½	23½			
6 "		20	23½	27	30	33	35½	37½	39	41	42½	43½	[illegible]
7 "			33½	38½	43½	47½	51½	55	58½	61	63½	66	[illegible]
8 "			44	51½	58½	64	70	76	80½	85	89	92½	[illegible]
9 "			56	65½	74	82½	91	98	105	114	116½	122½	[illegible]
10 "			70	80	91	101½	112	121½	131	139	147½	155	[illegible]
11 "			81	95½	109	122½	134½	146½	158	168½	179	188½	[illegible]
12 "			94	111	127½	143½	158½	172½	186	199½	212½	224	[illegible]
13 "			107½	127½	146	164	182	199	215½	231	246½	261	[illegible]
14 "			121½	143½	165	186	206½	226	245	263½	281	298½	[illegible]
15 "			135	160	184½	208½	231	253½	275½	296½	316½	336½	[illegible]
16 "			149	177	204	231	256	281½	306	329½	352½	375	[illegible]

COLUMNS 16 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
6 inches.		20	23½	26½	30	32	34	36	37½	38½	39	40	[illegible]
7 "			31	36	40½	44	48½	51½	54	57	59	61	[illegible]
8 "			41½	48½	54½	60½	66	71	75	79	83½	86½	[illegible]
9 "			52½	61½	70	78	85	92½	98½	104½	110	115	[illegible]
10 "			64	76	86½	96½	106	115	123½	131½	139	146	[illegible]
11 "			77½	91	104	116½	128½	139½	150	160½	170	179	[illegible]
12 "			90	106½	121½	136½	151	165	178	191	202½	214	[illegible]
13 "			103½	122½	140½	158	175	191	206½	221½	236	250	[illegible]
14 "			117	138½	159	179	198½	217½	236	253½	270½	286½	[illegible]
15 "			131	155	178½	201	223½	245	266	286	305½	324	[illegible]
16 "			144½	171½	197½	223½	248½	272½	296	318½	341	362½	[illegible]

COLUMNS 17 FEET LONG

THICKNESS

External Diameter	⅜in	½in	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛in	1¼in	1⅜in	1½in	1⅝in	1¾in	2 in.
6 incnes.		18	21½	24	26½	29	31	32½	33½	34½	35½	36	[illegible]
7 "			29	33½	37½	41½	45	48	51	53½	55	57	[illegible]
8 "			39	45½	51	56½	61½	66	71	74	78	81	[illegible]
9 "			50	58½	66	73½	80½	86½	93½	98½	103½	108½	[illegible]
10 "			61	72	82½	91½	101	109	117½	124½	131½	138½	[illegible]
11 "			73½	86½	99	111	122	132½	143	152½	161½	170	[illegible]
12 "			86½	101½	116½	131	144½	157½	170	181½	193½	204	[illegible]
13 "			99	117½	135	151½	167½	183½	198	212½	226	239	[illegible]
14 "			112½	133½	153½	172½	191	209	226½	243½	260	275½	[illegible]
15 "			126	149½	172½	194	216	236	256	276	294	312½	[illegible]
16 "			140	166	191	216	240	263½	286	308½	329½	350½	[illegible]

TABLE—Continued

(safe-bearing loads in tons, that hollow cast-iron columns may be employed of average uniform thickness, with their ends at planes and at right angles with the axis of the column, cap and base plates cast separately and planed. The breaking weight being six times greater. Read preceding article.

COLUMNS 18 FEET LONG

THICKNESS

xternal ameter	3/8 in	1/2 in	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in	1 1/4 in	1 3/8 in	1 1/2 in	1 5/8 in	1 3/4 in	2 in.
inches.				34½	38½	41½	45	47½	50	51½	53½	55	56½
"				42½	48½	53½	58½	62½	66½	70	73½	76	81
"				55	62½	69	76	82	87½	93	97½	102	110
"				68½	78½	87	96	103½	111	118½	125	131	141½
"				82½	94	106	116	123½	136	145	153½	161½	176½
"				97½	111½	125	138½	151	162½	173¼	184½	195	213½
"				112½	129	145½	161	176	190	203½	216½	229	252½
"				128½	147½	166	184	201½	218½	234	250	265	292½
"				144	166	187½	208	227½	247	266	283½	301	334
"				161	185	209	232½	254½	276½	297½	318½	338½	376½

COLUMNS 19 FEET LONG

THICKNESS

xternal ameter	3/8 in	1/2 in	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in	1 1/4 in	1 3/8 in	1 1/2 in	1 5/8 in	1 3/4 in	2 in.
inches.				31½	35	38½	41	43½	45½	47	48½	50	52
"				40	45½	50	54½	58½	62½	66	68½	71	76
"				52½	59	66	72	77½	82½	87½	92	96	103½
"				65	74	82½	91	98½	105½	111½	118½	124	134
"				79	90	101	111	121	129½	138½	146	154	168
"				93½	106½	120	132	144	155	166	176	186	204
"				108½	124	139½	154	168½	181½	195	207½	219	241½
"				123½	142	160	177	193½	210	225	240	254	281
"				139	161	181	201	220	238½	256	273½	290	321½
"				156	179	202½	224½	246	267½	287½	307½	326½	363½

COLUMNS 20 FEET LONG

THICKNESS

xternal ameter	3/8 in	1/2 in	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in	1 1/4 in	1 3/8 in	1 1/2 in	1 5/8 in	1 3/4 in	2 in.
inches.				38½	42½	47½	51½	55	58½	61½	64½	67	71
"				49½	56	62½	68	73½	78½	82½	86½	91	97½
"				61½	71	78½	86	93½	100	106	112	117½	127½
"				75	86	96	106	115	123½	131½	139	146½	160
"				89	102½	114½	126½	137½	148½	158½	168½	177½	194½
"				104	119	134	148½	161½	174½	186½	199	210	231½
"				119	136½	154	170½	186½	201½	216½	231	244	270
"				134½	155	174½	193½	211½	230	246½	263½	279	310
"				151	173½	196	217	238½	258½	278½	297	316	351

COLUMNS 21 FEET LONG

THICKNESS

xternal ameter	3/8 in	1/2 in	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in	1 1/4 in	1 3/8 in	1 1/2 in	1 5/8 in	1 3/4 in	2 in.
inches.					67	75	81½	88½	95	101	106½	111½	121
"					82	91½	101	109½	117½	125½	132½	139½	152
"					98	110	121	131½	141½	151½	161	169½	186
"					114½	128½	142	155	167½	179	191	201½	221½
"					131½	148½	164	179	194	208½	221½	235	259
"					150	168½	186½	204	221½	238½	254	269	298½
"					167½	189	210	230	250	268½	287	305	338½

COLUMNS 22 FEET LONG

THICKNESS

External Diameter	3/8 in	1/2 in	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in	1 1/4 in	1 3/8 in	1 1/2 in	1 5/8 in	1 3/4 in	2 in.
10 inches.					64	71	78	84	90	96	101	106	114½
11 "					78½	87½	96	104	112½	119½	126½	133½	145
12 "					93½	105	116	126	136	145	154	162	177½
13 "					110	123½	136½	148½	161	171½	183	193½	212½
14 "					126½	142½	158	172½	186½	200	213½	226	249
15 "					144	162½	171½	197	213½	229	245	259	287½
16 "					162½	183	203½	222½	241	259½	277½	294	326½

COLUMNS 23 FEET LONG

THICKNESS

External Diameter	3/8 in	1/2 in	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in	1 1/4 in	1 3/8 in	1 1/2 in	1 5/8 in	1 3/4 in	2 in.
10 inches.					61	67½	74	80	86	91	96	101	108½
11 "					75	84	91½	100	107½	114	121	126½	138½
12 "					90	101	111	121	130	139	147½	155	170
13 "					106	118½	131	143	154	165	175½	185	203½
14 "					122½	137½	152	166	179½	192½	205	217	239
15 "					139	156½	173½	190	206	221	236	250	276½
16 "					156½	176½	196	215	233½	251	268	284	316

COLUMNS 24 FEET LONG

THICKNESS

External Diameter	3/8 in	1/2 in	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in	1 1/4 in	1 3/8 in	1 1/2 in	1 5/8 in	1 3/4 in	2 in.
10 inches.						64½	71	76½	81½	86½	91½	96	103½
11 "						80	87½	95½	102½	109	115	121	131½
12 "						96½	106½	116	124½	133	141	148½	162½
13 "						114	126	137½	148½	158½	168½	177½	195
14 "						132½	146½	160	173	185½	197½	208½	230
15 "						151½	167½	183½	199	213½	227½	241	266½
16 "						171	190	208	225½	242½	259	275	305

COLUMNS 25 FEET LONG

THICKNESS

External Diameter	3/8 in	1/2 in	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in	1 1/4 in	1 3/8 in	1 1/2 in	1 5/8 in	1 3/4 in	2 in.
10 inches.						61½	67½	73	78½	83	87½	91½	98½
11 "						76½	84	91	98	104	110	116	126
12 "						92½	102	111	119	127½	135	142½	155½
13 "						109½	121	131½	142½	152½	161½	171	187½
14 "						127½	141	154	166½	178½	190	201	221½
15 "						146	161½	177	191½	206	219	232½	257
16 "						166	183½	201	218	234	250	265½	294

SQUARE HOLLOW CAST-IRON PILLARS

Safe loads in tons of 2,000 pounds that the following Cast-iron Rectangular Hollow Pillars will sustain, of ¾ inch and 1 inch in thickness, with their ends dressed in planes at right angles to their axes, with level cap and base plates, and to be employed at one-sixth their breaking weight. For further particulars read the article preceding the tables of round columns.

The computations of strength are made by

Gordon's Modification of Hodkinson's Formula for Square Hollow Cast-Iron Pillars

With flat ends, faced in machine, and equally loaded on their top. The single thickness of metal not to exceed one-eighth of width of side.

Find the area of solid metal in square inches contained in the transverse section of the pillar; square the length of the pillar in inches; also, square the least side in inches.

$$\text{Breaking load} = \frac{\text{Metal area in square inches} \times 80000}{1 + \left(\dfrac{\text{Square of length in inches}}{800 \times \text{square of least side in inches}}\right)}$$

a = Metal area in inches of transverse section.
b = Length of pillar in inches.
c = Least side in inches.
d = Breaking load in pounds.

$$d = \frac{a \times 80000}{1 + \left(\dfrac{b^2}{800 \times c^2}\right)}$$

Example.—What load is required to break a 16″ × 16″ square hollow cast-iron pillar, ¾″ thick, and 16′ 0″ long?

$$d = \frac{45.75 \times 80000}{1 + \left(\dfrac{192^2}{800 \times 16^2}\right)} = \frac{3660000}{1.18} \text{ or } 3101695 \text{ lbs.}$$

or 1550 8-10 tons breaking load.

The safe load taken at 1-6 the breaking load = 258 tons. This will safely sustain a solid 16-inch brick wall, 25 feet in width and 184 feet high, or equal to a 16-inch thick brick wall, 25 feet in width and 14 stories high; height of each story 13 feet.

If it was a brick pier and employed at 18 tons per square foot, would require to be to sustain the load, 4 feet wide and 3 feet 6 inches deep.

¾ inch thick			
Length in feet	Size in Inches	Safe Load in Tons	
10	8 x 10	129	....
12		117½	....
14		106½	....
16		96	....
18		86½	....
10	8 x 12	144½	....
12		131	....
14		117	....
16		108	....
...		.....	....
10	8 x 14	160	....
12		146	....
14		132	....
16		117	....
...		.....	....
10	8 x 16	175½	....
12		160	....
14		145	....
16		131	....
...		.....	....
10	8 x 18	191	....
12		174½	....
14		158	....
16		143	....
...		.....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

¾ inch thick			1 inch thick
Length in feet	Size in Inches	Safe Load in Tons	Safe Load in Tons
10	10 x 10	156½	203½
12		146½	190½
14		137	177½
16		126½	164½
18		.....	151½
10	10 x 12	173½	226
12		163	212
14		151½	197
16		140½	182½
18		......	168½
10	10 x 14	190½	248½
12		178½	233
14		166½	217
16		154	201
18		......	185½
10	10 x 16	207½	271
12		194½	254
14		181	236½
16		167½	219
18		......	202
10	10 x 18	224½	294
12		210½	275½
14		196	256½
16		.....	237½
18		......	219
10	10 x 20	241½	316½
12		226½	296½
14		210½	276
16		......	255½
18		......	236

¾ inch thick			1 inch thick
Length in feet	Size in Inches	Safe Load in Tons	Safe Load in Tons
10	12 x 12	200	260½
12		190½	248½
14		180½	235½
16		170½	222
18		.....	209
10	12 x 14	218	284½
12		207½	271
14		197	257
16		185½	242½
18		.....	228
10	12 x 16	235½	308
12		224½	294
14		213	278½
16		201	262½
18		......	246½
10	12 x 18	253½	332
12		241½	316½
14		229	300
16		.....	283
18		......	265½
10	12 x 20	271	355½
12		258½	339
14		......	321½
16		......	303
18		......	285
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

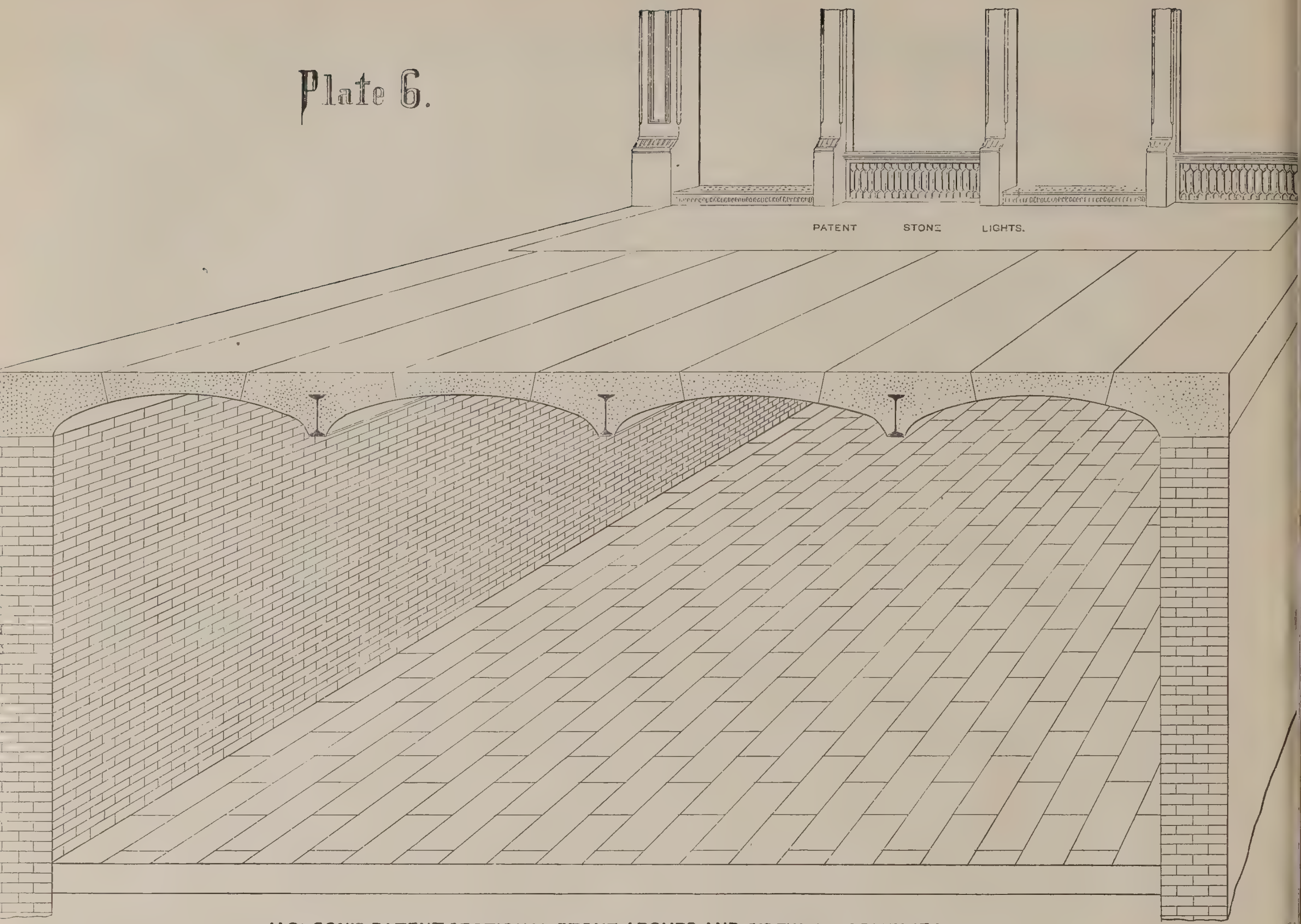
¾ inch thick			1 inch thick
Length in Feet	Size in Inches	Safe Load in Tons	Safe Load in Tons
10	14 x 14	242½	317½
12		234	306
14		224½	294
16		214½	280½
18		......	267
10	14 x 16	261	342
12		251½	329½
14		241½	316½
16		231	302½
18		......	287½
10	14 x 18	279½	366½
12		269½	353½
14		258½	339
16		......	324
18		......	308½
10	14 x 20	297½	391
12		287	377
14		......	361½
16		......	345½
18		......	329
10	14 x 22	316	415
12		304½	400½
14		......	384½
16		......	367
18		......	349½
10	14 x 24	334½	439½
12		322½	424
14		......	407
16		......	388½
18		......	370

SQUARE HOLLOW CAST-IRON PILLARS—TABLE—Continued

¾ inch thick			1 inch thick	¾ inch thick			1 inch thick	¾ inch thick			1 inch thick	¾ inch thick			1 inch thick
Length in Feet	Size in Inches	Safe Load in Tons	Safe Load in Tons	Length in feet	Size in Inches	Safe Load in Tons	Safe Load in Tons	Length in Feet	Size in Inches	Safe Load in Tons	Safe Load in Tons	Length in feet	Size in Inches	Safe Load in Tons	Safe Load in Tons
10	16 x 16	285	373½	10	18 x 18	327	429½	10	18 x 28	...	555½	10	20 x 20	368½	485
12		277	363	12		319½	419½	12		...	543	12		...	476
14		268	351½	14		...	409	14		...	529	14		...	465½
16		258	339	16		...	397	16		...	513½	16		...	454½
18		...	326	18		...	384	...		...	...	18		...	442
10	16 x 18	303½	398½	10	18 x 20	345½	4[illegible]4½	10	18 x 30	...	581	10	20 x 22	...	510½
12		295	387½	12		338	444½	12		...	568	12		...	501
14		285½	375	14		...	433	14		...	553	14		...	490
16		...	361½	16		...	420	...		...	...	16		...	478½
18		...	347½	18		...	406½	...	...	...	...	18		...	...
10	16 x 20	322½	423½	10	18 x 22	...	480	...	...	...	...	10	20 x 24	...	536
12		313½	411½	12		...	469	...	...	...	...	12		...	526
14		...	348½	14		...	455½	...	...	...	...	14		...	514½
16		...	384	16		...	443½	...	...	...	...	16		...	502
18		...	369	18		...	429½	...	...	...	...	18		...	...
10	16 x 22	341	448½	10	18 x 24	...	505½	...	...	...	...	10	20 x 26	...	561½
12		...	436	12		...	494	...	...	...	...	12		...	551
14		...	422	14		...	481	...	...	...	...	14		...	539
16		...	407	16		...	467	...	...	...	...	16		...	526
18		...	...	...		...	...	...	...	...	...	...		...	...
10	16 x 24	...	473½	10	18 x 26	...	530½	...	...	...	...	10	20 x 28	...	587
12		...	460	12		...	518½	...	...	...	...	12		...	576
14		...	445½	14		...	505	...	...	...	...	14		...	568½
16		...	429½	16		...	490½	...	...	...	...	16		...	...
18		...	...	...		...	...	...	...	...	...	18		...	...
...	...	...	...	...	...	...	...	...	...	...	...	10	20 x 30	...	612½
...	...	...	...	...	...	...	...	...	...	...	...	12		...	602
...	...	...	...	...	...	...	...	...	...	...	...	14		...	588
...	...	...	...	...	...	...	...	...	...	...	...	16		...	...
...	...	...	...	...	...	...	...	...	...	...	...	18		...	...

For longer lengths of the sizes given, increase the thickness of metal, otherwise the Molten metal will chill in green sand before the mould is properly filled, and the casting would be imperfect and unfit for use.

Plate 6.



JACKSON'S PATENT SECTIONAL STONE ARCHES AND SIDEWALK COMBINED.

JACKSON'S

Patent Sectional Artificial Stone Sidewalk and Arches with Iron Beams

See Plate 6.

First—The arch and sidewalk are one in thickness, therefore the two are united in the strength of the arch, and require less material than if the sidewalk was an idle load to be sustained by the arch; also the combined arches and sidewalk are made in sections, so that they wedge the parts, employing the concrete material in its great compressive strength, by which less expensive material may be used: these two reduce the cost.

Second—The combined arch and sidewalk are about four inches less in thickness than when made separately in the common way, the four inches are added to the height of the apartment beneath, which is particularly advantageous where the earth has been filled in, and will not admit of deep excavation before coming to water.

Third—Each section is free to shrink when solidifying and hardening from the plastic state independently of the adjoining section on each side, which prevents cracking or separation of the parts, and the wedge or key-stone section resting on the tapering sides of the adjoining sections wedge and compress them, and their resistance in turn compresses the key-stone section, thereby urging all shrinkages and employing the concrete in its great compressive strength, without engaging its comparative feeble tensile strength.

See quotation from General Gilmore's work on Artificial Stone, page 15 of this book, respecting the great compressive strength of Portland Cement Concrete compared to its tensile strength. It is formed as follows:

Referring to plate 6. First, the iron or steel beams are set in position, and the centers formed, taking their support on the bottom flanges of the beams. The two end sections that rest upon the walls, with the three middle sections in which are built the beams, are first formed. The sides of these five supporting sections are made by setting planed planks on edges, resting upon the centers, and set at angles radiating to the curve of the arch, and at distances apart as required for each section. Then tarred paper, cloth, or other equivalent material to prevent escape of moisture from the concrete to be smoothly laid on the centers; and the concrete, to be of a mixture given further on, is then filled in between the planks, and suitably compacted with iron rammers about every four inches in thickness. The concrete at the sides and tops of the beams to be well compacted, and should be about four inches of concrete on top the beams. The rise of arches to be, as nearly as possible, 1½ inches to every foot of span.

The top surface of each layer to be well scarified with a trowel and wetted before another layer is added, and if the bottom layer is left too long the surface should be removed and well coated with liquid Portland cement before adding the next layer.

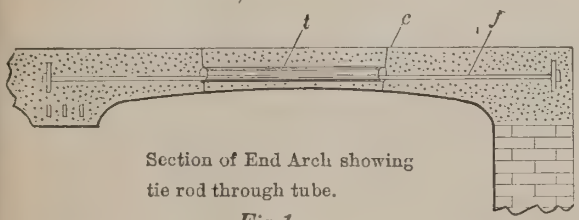
The top, 1¼ inches in thickness forming the sidewalk surface, to be of equal portions of best Portland cement and gravel, and to be smoothed and finished in the manner usual in making artificial stone sidewalks. Thirty hours after finishing these five supporting sections, the planks forming the sides to be withdrawn and the sides to be plastered quite smooth with Portland cement.

Allow five days after finishing for the artificial stone concrete to harden, then some separating material, as tarred paper, smooth cloth or equivalent material, to be placed smoothly against the sides where the planks set at angles were.

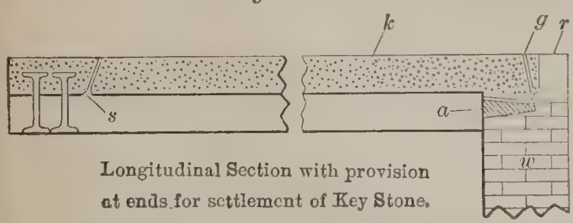
This has finished the five supporting sections; then fill in the keystone sections between the tarred paper, with particular attention to keeping it smooth, compact in layers, etc., as before described. For arches not exceeding 6 feet span the crowns to be 5 inches thick, over and up to 7 feet 6 inches span 5½ inches thick, over and up to 9 feet 6 inches thick, and to be increased in proportion.

Rise 1½ inches to every foot of span.

To provide for the Horizontal Thrust of the End Arch where the end rests upon the wall, and to allow the keystone section to settle and depend entirely on the tapering sides of the side sections—It is usual to employ for this purpose two iron tie rods, with one end inserted either through the web of the beam or attached to its top flange, and the other end to have a long anchor plate, either resting upon or above the wall.



Section of End Arch showing tie rod through tube.
Fig. 1.



Longitudinal Section with provision at ends for settlement of Key Stone.
Fig. 2.

Figure 1 of the accompanying illustration was drawn in explanation of plate 2, and has three of Hyatt's ties in the footing in place of the metal beam adapted to plate 6. Referring to figure 1 (*f*) is one of the tie rods before mentioned which passes through the end arch with an anchor plate on each end.

As the keystone (*c*) in the figure must slip down and rest upon the tapering sides and be independent of the rod; to meet the requirement have a water-tight thin tin tube (*t*) of oblong shape, say ⅝ of an inch larger the greater way than the rod (*f*) and to be the length of keystone, and with ends of the exact shape of what the tapering sides of the keystone is to be. Press the tube above the rod as shown in the figure and keep it there, then press in from the end of the tube common brown soap, or stiff putty, the former preferred, so as to keep the tube above the rod, or it may be held up by strings when in place. The soap also prevents the concrete from entering the tube. Use as little soap as possible for the purpose.

When the keystone is formed and has become dry and hard, and the centers are dropped, the soap in the tube will be crushed, and the keystone will drop fully half an inch before touching the rod.

The tie rod (*f*) resists the horizontal thrust of the arch, and the keystone is independent of the rod in settlement.

The Keystone Sections of Plates 2 and 6 must not rest upon any end support, but depend entirely on the tapering sides of the supporting sections—There are two ways of meeting this requirement. Refer to figure 2 of the preceding illustration; at the left at (*s*) is shown a tapering separation which permits the keystone to settle independent of the part resting on the two beams forming the vault girder. This tapering separation to be formed in the manner described for the tapering sides, but the taper to be the reverse way. The division (*s*) extends only the width of the keystone. The other end of the keystone at the right hand of figure 1, to be separated in the same way as (*s*), and to be just inside the end support.

To prevent leak at these two seams, cut a groove at the bottom as shown at (*s*), to be quite deep compared to its width to hold the Portland cement filling to be applied, which will close the seams against leak.

In place of cutting grooves, pieces of wood grooved shape may be laid on the centers at the seam, to be well oiled or soaped, and the concrete formed on them, and when the centers are dropped, withdraw the wood pieces and fill in with Portland Cement.

The other way, is to make a large wedge—piece of wood—(*a*), of about 1¼ inch taper to the foot, and of a length the width of keystone. Make the tapering division (*g*). When the concrete is dry and hard withdraw in the vault the wedge (*a*) and after the keystone has settled in position, fill in the space where the wedge was with concrete.

The former method preferred, (*r*), is the curbstone, and (*w*) the wall under it.

An artificial stone or concrete body, be it a sidewalk, arch, or arch and sidewalk combined, the same as a body of cast iron, and in common with every material that shrinks, when solidifying from a plastic or molten state, will occupy less space when solidified than it did in the plastic or melted state, and if held so it cannot shrink, as a series of continuous arches, or a sidewalk in one piece, it will separate in parts; or if made in large sections, and has not the strength from its thinness compared to its length and breadth to draw the extremities towards a common center, it will also crack.

Also if of irregular thickness, as that of an arch in one piece, thin at the crown and thick through the haunches and footings, the thick parts being of greater shrinkage strength, will draw to themselves towards each footing, and crack the thin bridging part between.

But with arches in sections, as in plates 2 and 6, the shrinkage is not only taken up by being in sections, but great wedge pressure is exerted in the direction of the contracting material.

CONCRETE MIXTURE FOR PLATE 6

For the bottom up to 1¼ inches of the top, the mixture to be as follows:

First, a cement mortar to be made, and afterwards to be mixed with an aggregate.

The cement mortar to consist of one measure of *best* Portland cement to three measures of clean sharp gravel that will pass through a 3-16 mesh, and a half a measure of clean sharp sand entirely free from loam, to be well mixed with a small quantity of water gradually applied with a rose sprinkler; and to be thoroughly mixed by several turnings over with shovels, incorporating the parts so that the surfaces of the gravel and sand are entirely coated with the cement. The water to be applied only after the cement is well mixed with the gravel and sand, and then to be well mixed again. This forms a stiff cement mortar. Then measure in another place four volumes, or may in some cases be 4½ volumes of either clean broken granite, blue-stone, basalt rock or equivalent in value, angular chips (round stones will not do) that will pass through a 3-inch ring. Wet thoroughly so as to coat well the surfaces of the stone before mixing with the mortar. Then thoroughly mix it by repeated turning with shovels in the before-described cement mortar. The cement mortar will more than coat the surfaces and fill the interstices of the stone chips. The mortar bears the same cementitious relation to the stone, as mortar does to laid up brick forming brickwork. The addition of the stone does not impair the strength of the structure, any more than if all was of mortar omitting the stone, providing the adhesion and cohesion are equal.

The concrete mixture must be used soon after mixing. Never mix a batch and the men go to dinner, if so, it must not be used; delay after mixing seriously injures its strength, as setting commences directly after mixing with water. Should there be delay in adding a layer of concrete on a bottom one, the latter must have its surface scraped off and coated with liquid Portland cement before the succeeding layer is applied.

Slow setting Portland cement, as that of Dyckerhoof's and others, should be preferred to those that set quickly.

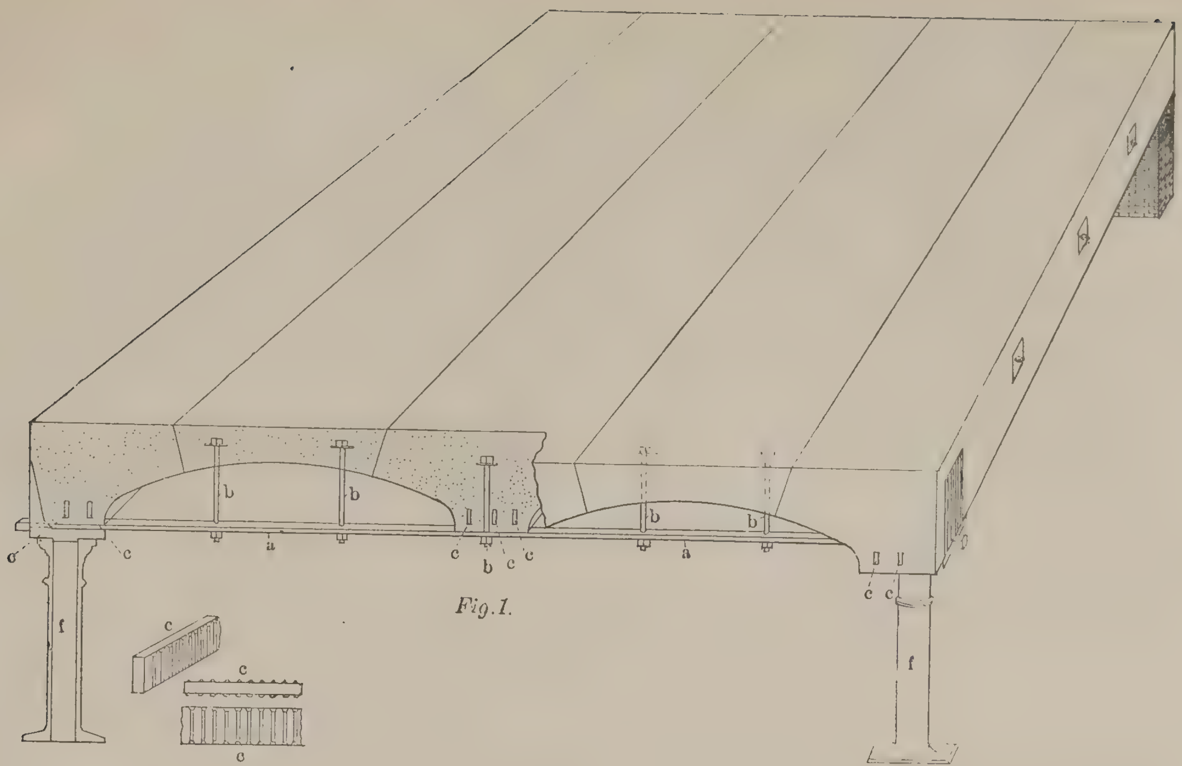


Fig.1.

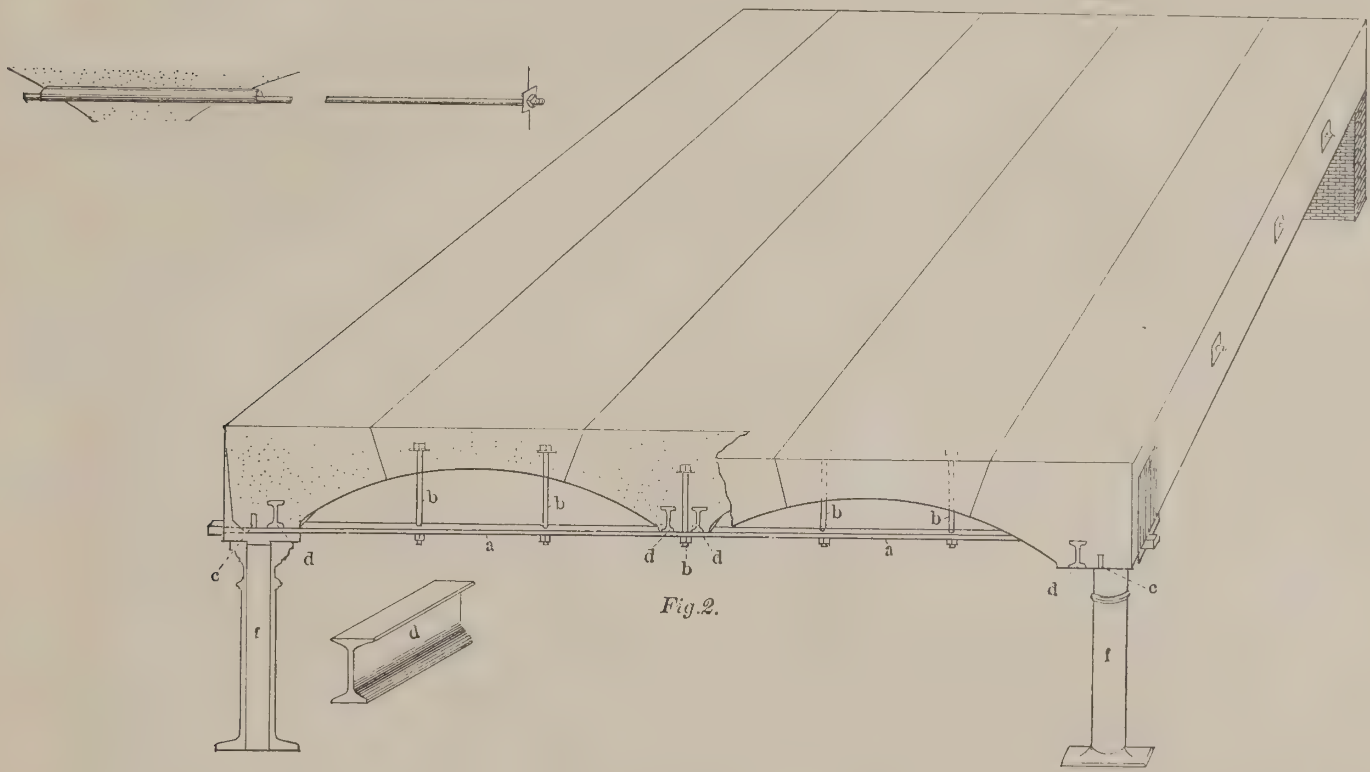


Fig.2.

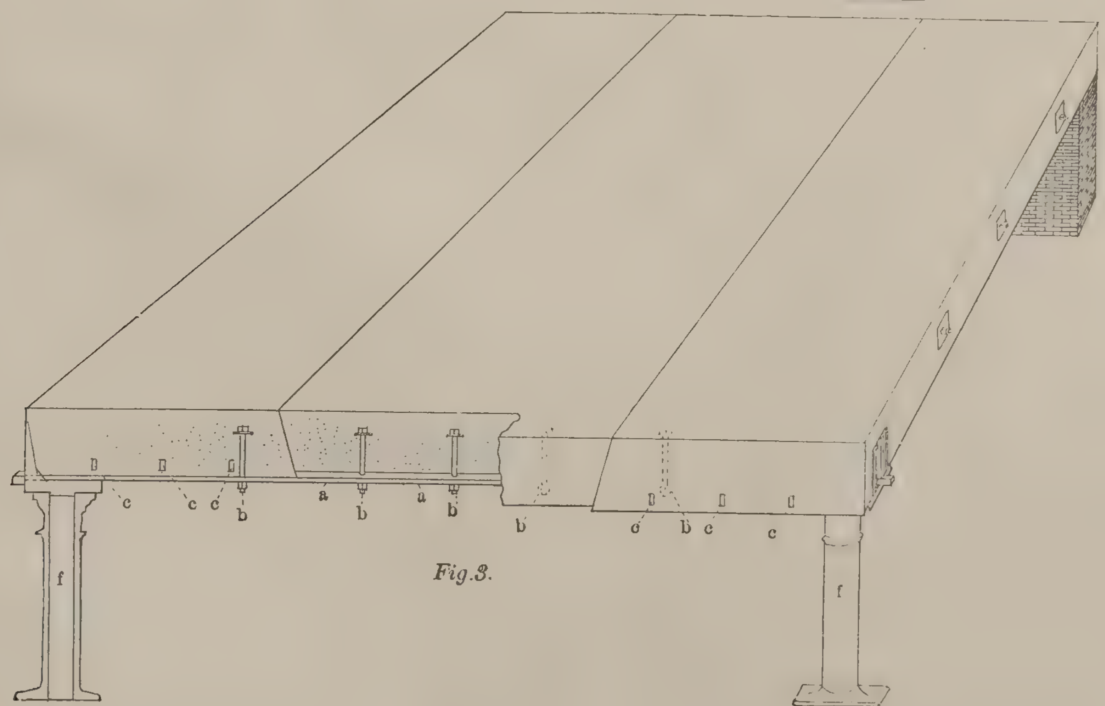


Fig.3.

Combined Artificial Stone Sidewalks and Arches, dispensing with girders as well as beams, made for experimental purposes, to be broken to ascertain their strengths—The engravings, figures 1, 2 and 3, each illustrate Jackson's Patent Combined Artificial Stone Sidewalks and Arches, their bottom surfaces are intended to form roofs to the vaults beneath.

Figure 3 is of flat arches, the other two segmental. They are equally suited for fireproof floors by mixing in the concrete the before mentioned refractory materials. This construction is equally adapted for bridges. It dispenses with iron or steel beams and girders, by employing the great compressive strength of the artificial stone or concrete above the neutral axis in *resisting compressive force in both direct and cross directions,* aiding two-thirds in its own support by performing the functions of the top flanges and webs of iron beams and girders. The iron or steel ties attached to and in the bottom, *resist tensile strains in both direct and cross directions, performing the duties of the bottom flanges of beams, and girders as well.*

A full-sized construction of each kind, illustrated by figures 1, 2 and 3, are now on the lot No. 302 Beale Street, this City. They were made for experimental purposes, and will shortly be tested with loaded pig iron to ascertain their respective strengths, the result in detail will be published. They were made for trial as sidewalks; the brick wall at the back of each represents the outer wall of a vault under the curbstone; the front is supported on two 6-inch round iron columns, representing the columns under a vault girder.

The mixture of concrete in all of them is:

1 part measure Portland cement.
3 parts " fine gravel.
$2\frac{1}{2}$ " " broken stone that will pass through a 3-inch ring.

Figures 1 and 2 are 13 feet wide, figure 3, 12 feet wide, and all 18 feet 6 inches deep, resting on a 13-inch brick wall at the back. The front of all of them overhangs the columns 1 foot 6 inches, in order to have sufficient concrete material on each side of the tie over it to resist the required compressive force, of what would be the top flange of the girder part. The iron tie rods (*a*) are each 6 x $\frac{7}{8}$-inch, with a 1 inch hole for the bolts (*d*), which reduces its area for strength to 5 x $\frac{7}{8}$ inch. Cast-iron screw-backs, o, resist the horizontal thrust at the ends. The top of the bolts, d, are built in the concrete and pass down through the tie, a, and with a nut on the ends, which, when tightened produces tension on the tie rod between each footing; by this means the tensile strain on the tie between each footing is graduated at will.

Three of Hyatt's iron ties, c. c. c. (in what would be the beam part) are in the middle footing of figure 1 of the kind shown in the sections, they have a combined area of $4\frac{8}{10}$ inches. In figure 2, two of 4-inch rolled iron beams and plates are used in the middle footing, of a combined area of 5 inches, being slightly in excess of the Hyatt ties in the middle footing of figure 1. Rise of arch, $10\frac{1}{2}$ inches, thickness at crown of figure 1 6 inches.

To resist the horizontal thrust of the end sections as there are no abutting arches, three of $\frac{7}{8}$-inch iron tie rods with plates on ends are used in each, and with oblong tin pipes on the rods to permit the keystone sections to slide down independent of the rods and rest on the tapering sides of the supporting sections, as explained in description of plates 2 and 6. Distance from top surface to bottom of ties in figure 1 is $15\frac{1}{2}$ inches, and to bottom of the 4-inch beams in figure 2 is $16\frac{1}{2}$ inches; the latter being favored for strength by the increased depth.

Figure 3 is a flat arch in sections. The operation of tightening the tie rod (*a*) by means of the nuts on the bottom ends of bolts (*b*) is the same as described for figures 1 and 2. The keystone section will be seen on reference to the drawing, does not rest upon the tie rod but is one inch or more above it, and when the nut on the bottom of the vertical bolt (*b*) is tightened, it not only produces tensile strain on the tie rod, but it draws down the keystone section, which compresses the concrete and tends to expand the distance across, producing additional tensile strain on the tie.

The distance from top surface to bottom of the Hyatt ties is 10 inches.

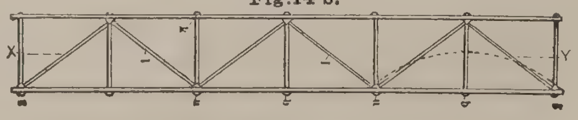
The area of the three Hyatt's iron ties in each supporting section is $5\frac{7}{100}$ inches.

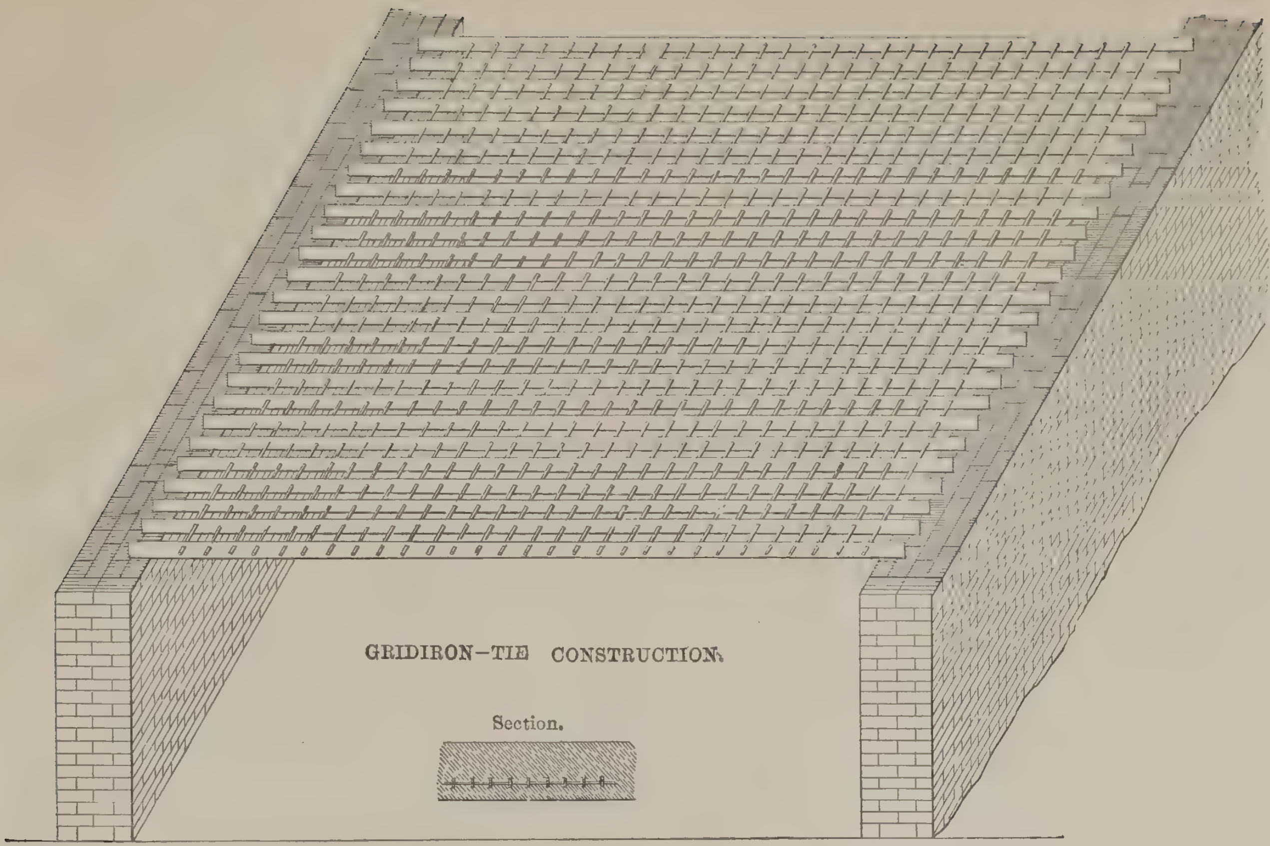
Each of the figures shows at the left, the arch and sidewalk cut through on a vertical line directly over one-half the width of the tie rod and column. At the right of each of the figures is shown the sidewalk of full construction, extending 1 foot 6 inches in front of the center of column, for the purpose as before described.

The forces exerted upon the front or girder part of figures 1 and 2, are somewhat similar to the truss in the following figure, with the decided advantage of all the parts being firmly held, and held against any lateral movement.

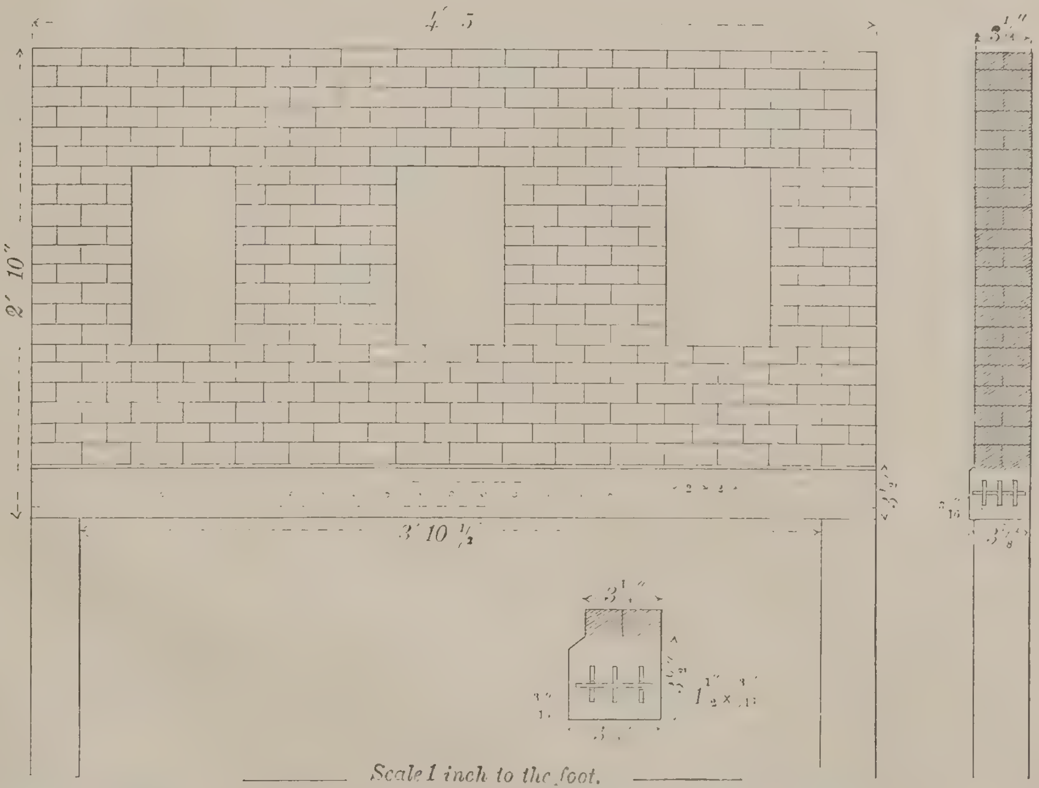
The dotted arched line to the right of the figure stands for an arch of the concrete construction.

Fig.14 b.





The above is Hyatt's Patent Gridiron Tie Construction for concrete floors. The ties in the bottom built in the concrete resist the tensile strain, and the concrete above the neutral axis resists the compressive force. It is of reduced cost compared to beams; is well adapted for prison floors, floors of banks and walls as well, to resist burglars cutting through from below, and from the sides when Hyatt ties bars are built in the walls.



Jackson's Patented Method of making Brick and Stone Walls Self-Supporting, and of great strength, dispensing with costly Iron or Steel Girders and making the lower part Fire-proof.—Result of Experiment. The above cut illustrates a model of a front brick wall of a building made of small common baked brick, especially made for the experiment, and laid up with Portland cement mortar, of a mixture of 1 volume of cement to 3½ of sand. The bottom course of bricks of the wall was built into a body of Portland cement concrete, which latter may be of the fire-proof kind used in the Hyatt's experiment described on page 21. In the Portland cement concrete there were three of Hyatt's iron ties, each 1½ x $\frac{3}{16}$ inches, crossed by $\frac{3}{16}$ inch iron wires, every 2 inches from centers. Deducting for the $\frac{3}{16}$ holes for the cross wire in the three ties, the area of their cross section is $\frac{73}{100}$ of an inch of iron. This resisted the tensile strain.

The wall aids in its own support in performing the functions of a top flange, ***and the web of very great depth*** of an iron beam or girder; the equivalent in strength of the bottom flange of the beam, is supplied by the Hyatt ties built and held in the concrete bond at the bottom of the wall. For a full-sized wall, would use the kind of ties shown in figure 3, Plate 4.

The combination is on the beam principle, and is equivalent to an iron girder with the bottom flange of $\frac{73}{100}$ of an inch, balanced by an equivalent to a top flange largely in excess of requirement, and the two connected by a web of very great depth. In the computation of strength of a rectangular wooden beam or girder, we multiply its width ***by the square of its depth.***

A wall of this construction with the brickwork at the bottom and a few courses of it laid up in Portland cement mortar, bears the same relation for strength up to a certain height, as that of the depth of a beam whose calculation for strength is in the square of its depth This accounts for the enormous strength developed in the single effort to break the wall combination, made of the form in the preceding illustration, and of the dimensions given by the figures. The pig iron was piled 7 feet 10 inches high, within 3 feet of the roof. The pigs of iron were laid cross ways of the 3¼ inch thick brick wall and had to be balanced on that fulcrum. When it had reached the height given, 28,070 pounds, or 14 tons, were upon it; piled between vertical lines over and just inside of the bottom supports. From fear of the iron canting on the men piling, also from fear of either one of the two post supports giving away, it was considered imprudent to continue after the 14 tons had been laid on, besides the men were in too close proximity to the roof to continue. This weight remained on from Saturday afternoon till Monday following. The greatest deflection was one-sixteenth of an inch. Four small cracks about one-thirty-second of an inch were observable in the brickwork, not in the center, but just inside of the right and left window. Upon close examination the reader will see in the illustration white spots showing the line of cracks. When relieved of the load the cracks closed, and to trace them a magnifying glass had to be used.

The concrete bottom with the inclosed ties are as perfect as when first made; and as far as they are concerned in the combination, from experience which I have had in several trials of concrete beams combined with iron on the Hyatt principle, I believe they would have sustained over five times the weight as applied and transmitted in the manner they were subjected to. The window openings were each 6½ x 11 inches.

The concrete inclosing the tiles may be made refractory as before described in the Hyatt experiment, page 21.

The following testimonial from Mr. G. W. Percy, of the firm of Percy & Hamilton, Architects of the Academy of Sciences Building now erecting in this city. A large fire-proof building, with concrete floors and metallic ties throughout, of from 20 to 30 feet span.

OFFICE OF
PERCY & HAMILTON
ARCHITECTS
No. 318 Pine Street

SAN FRANCISCO, December 26, 1889.

P. H. JACKSON, ESQ.

DEAR SIR: It gave me pleasure to accept your invitation of the 21st inst. to witness the loading of your model of brick front at McCormick's Foundry.

I was present when the last of fourteen tons of pig iron was placed on the model, which showed a deflection of one-sixteenth inch only, and very fine cracks could be observed.

It was with considerable difficulty that this great mass of iron was balanced on such a small base, and it did not appear prudent to make the pile higher, as there was danger of its toppling over. This experiment demonstrated the practicability of uniting iron ties and brickwork in such a manner that the wall itself shall form a girder, an application that may often be useful to the architect and engineer.

That careful workmanship and good materials are necessary for such application is evident from the nature and directions of the strains.

Hoping to witness further developments in this line, I remain,

Yours truly,

G. W. PERCY.

Figure 7 is a cross section of a brick wall with iron ties bedded in the concrete at the bottom, and cornice attached to the wall. Fire brick tiling inclose the concrete and ties. The concrete may be made refractory.

Figure 8 are cross sections of artificial stone stairs with cross ties and bearers built in the concrete.

Fig 8.

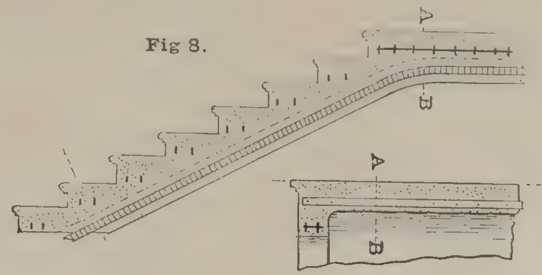
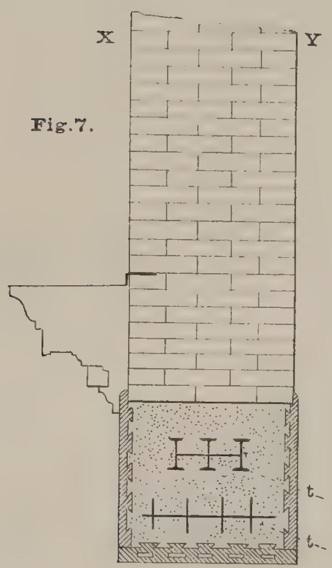


Fig. 7.



Figures 2, 4, 5 and 6 is of concrete with terra cotta, fire-brick, or other fireproof tiling, for fireproof floors—dispensing with metallic beams and employing Hyatt Ties in the concrete body. Patents pending. *t. t.* are Hyatt ties.

Fig. 4.

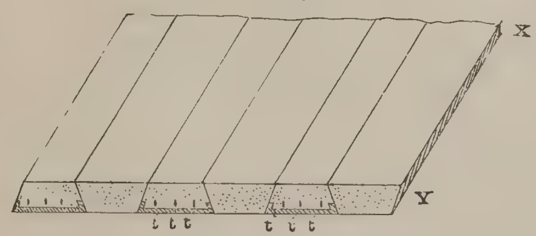


Fig. 1.

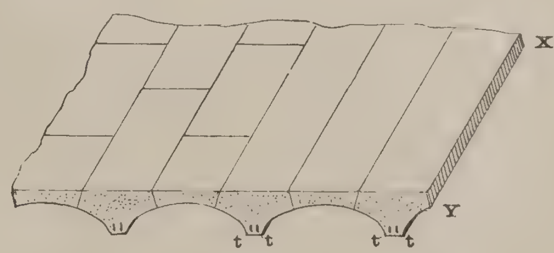


Fig. 5.

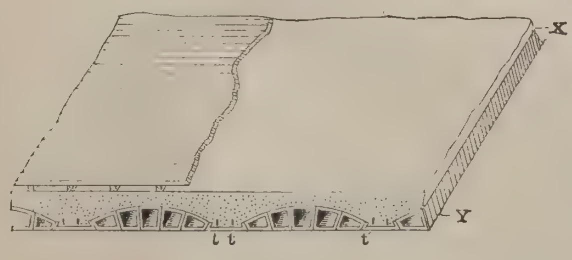


Fig. 2.

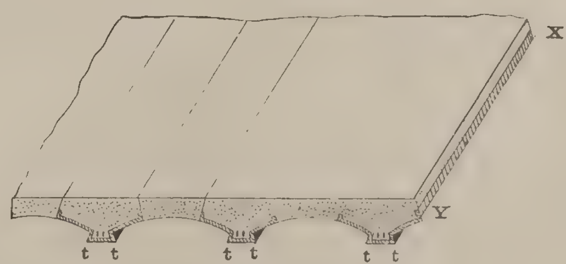


Fig. 6.

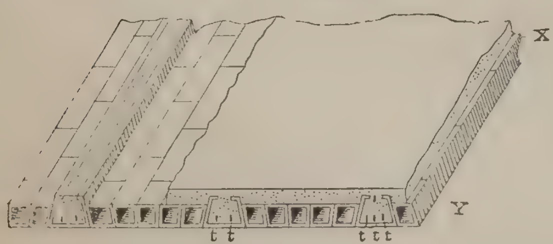
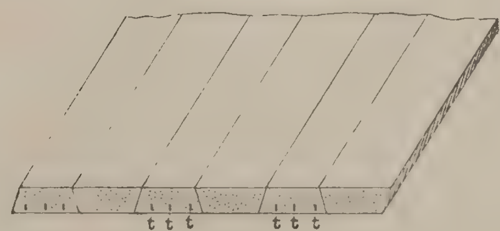
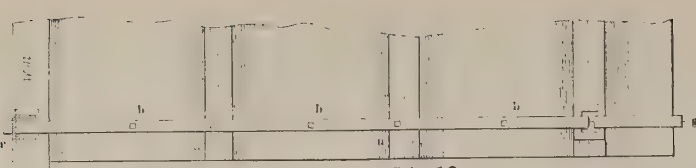


Fig. 3.





Plan Under Side Fig.10

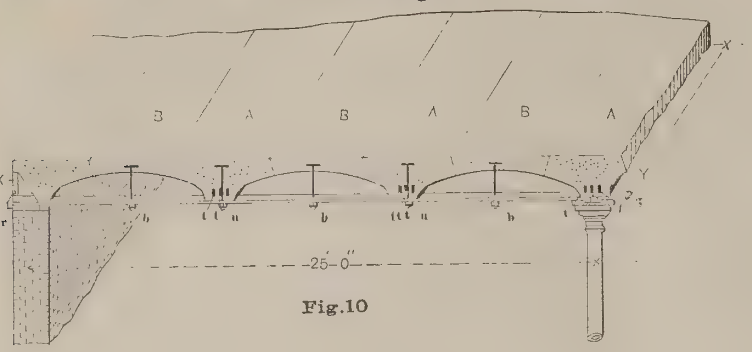


Fig.10

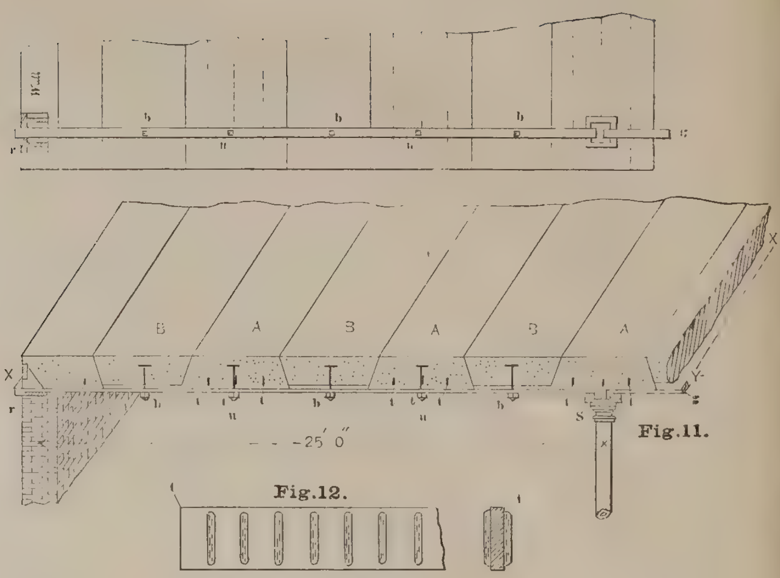


Fig.11.

Fig.12.

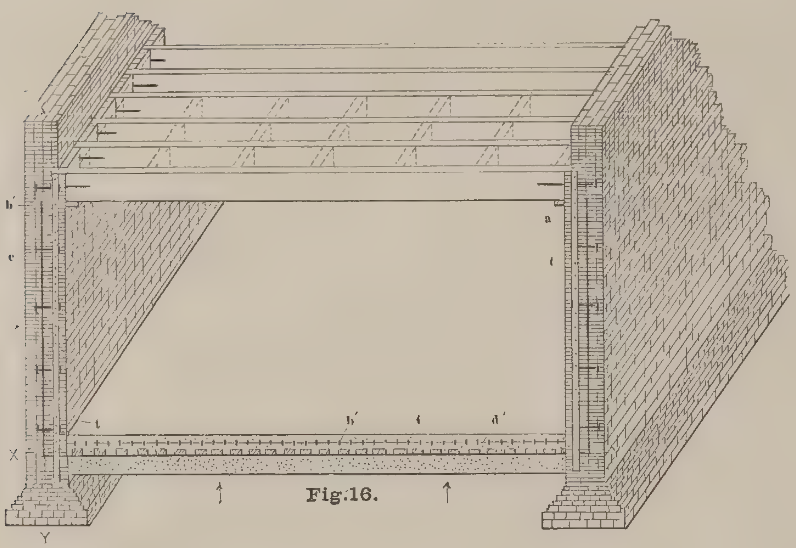


Fig.16.

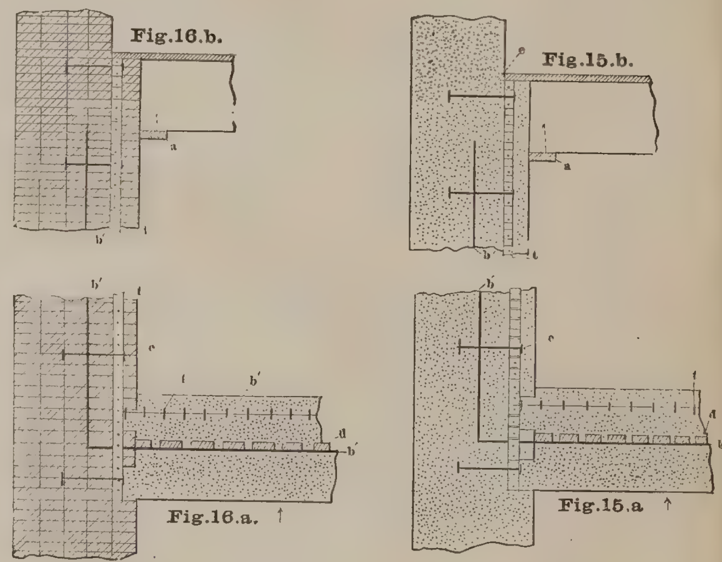


Fig.16.b. Fig.15.b. Fig.16.a. Fig.15.a

Figure 16 is a waterproof basement made to resist water pressure from the bottom and at the sides. The figures at the right are sections of the parts. Patents pending. Figures 10 and 12 illustrate combined artificial stone sidewalks and arches before described, also are adapted to fireproof floors dispensing with metallic beams and girders

The following communication was received in response to a request as to the transverse strength of Oregon Pine, from Mr. Calvin Brown, late U. S. Government Engineer; who during 18 years service at Mare Island made many scientific experiments as to the strength of materials, etc.

P. H. JACKSON, ESQ.

SAN FRANCISCO, November 13, 1889.

DEAR SIR: At your request I herein give you the results of tests of the strength of various woods made by me at Mare Island in 1871, with my deductions as to the constants which should be used in estimating dimensions of beams of these woods in constructive applications.

The samples operated upon were California Laurel, Oregon Pine and Eastern White Oak. The latter wood being taken with the view of comparing the Oregon Pine with it; all samples being accurately dressed to a square section of one inch, straight, and of a length to give exactly two feet between supports when the weights were applied. These samples were also varied as to the direction of the grain in the cross section, so that when placed in position for the breaking weights some of them would have the grain vertical, others horizontal, and the rest diagonal. This arrangement being made for the purpose of obtaining such an average of conditions as would be likely to occur in building practice.

The actual breaking weights centrally applied to the samples and constants reduced to lengths of one foot between supports were as follows:

	Average Breaking Weight in Pounds at 2 feet between supports	Constants for 1 lineal foot between supports
California Laurel	326	652
Eastern White Oak	396	792
Oregon Pine	373	746

From these results it appears that Oregon Pine is very nearly as strong as seasoned Eastern White Oak, with a far greater stiffness, as shown by the carefully noted deflections of the samples under the weights.

As a matter of safety I use the number 700 as a Constant in Oregon Pine for tranverse strain for beams, and take say ¼ the central breaking weight for a permanent load upon the center of the beam.

The usual formula for determining the central breaking weight of a beam. Calling central weight *b w*, breadth in inches *a*, depth in inches *c*, and length in feet *l*, and for Oregon Pine a Constant of 700 is as follows:

$$\text{B W} = \frac{\text{A} \times \text{C}^2}{\text{L}} \times 700$$

For a practical sample take an Oregon Pine beam 10 inches in breadth by 12 inches in depth, and 10 feet between supports, what is the central breaking weight?

$$\frac{10 \times 12^2}{10} \times 700 = 100800 \text{ lbs., or } 50\tfrac{4}{10} \text{ tons.}$$

for the breaking weight applied at the center of the beam. Double that weight for an equally distributed load which equals $100\frac{8}{10}$ tons. Employ at ¼ for a load at rest, would be for a central load $12\frac{6}{10}$ tons, for an equally distributed load $25\frac{2}{10}$ tons.

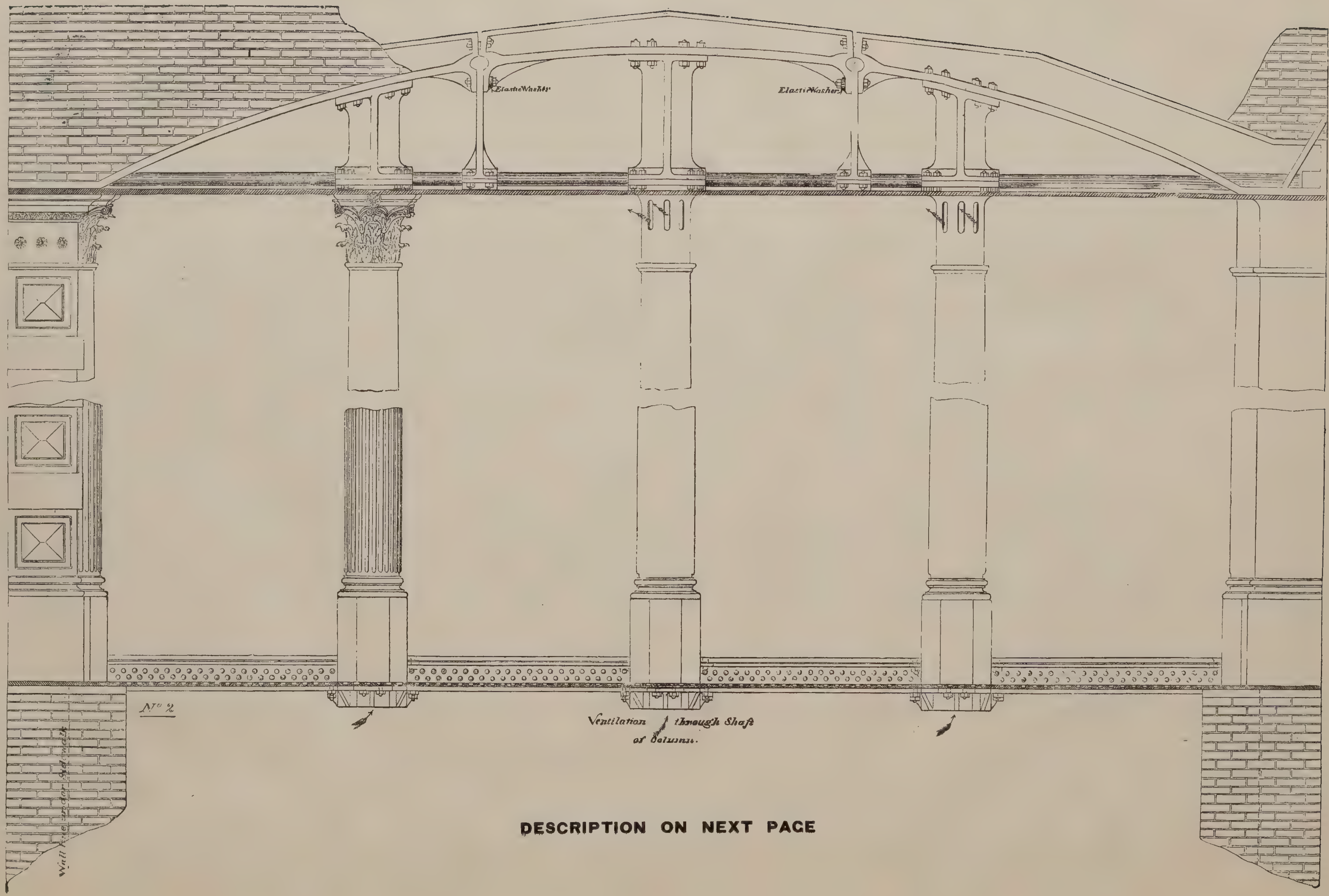
As for the breaking loads of square pillars of these woods, we may consult the tables in Trautwine's "Civil Engineers' Pocket Book", pages 459, 460 and 461, for a comparison of such loads as are there given for white and yellow pine, observing that the transverse strength of these two woods represented by constant 450 and 500 respectively (page 493) or a mean of 475, show 72% for Laurel, 60% for Eastern White Oak, and 63% for Oregon Pine. Although perhaps not rigidly correct, we may, I think, safely add at least 15% to the tabular breaking loads on the above pages for the last two woods; and say 10% for the Laurel.

Thus taking from the table, page 461, the breaking load of a square pine pillar 20 inches wide and 10 feet high, we find it set down at 780 tons; if, therefore, we add to this 15% or 117 tons, we shall have 897 tons as the breaking load of an Oregon pine pillar of these dimensions. This is merely approximative as to the ***breaking load,*** and implies, of course, that in the pillars a proper co-efficient should be taken for safety, according to the circumstances and purposes of construction.

Yours truly,

CALVIN BROWN,

Civil Engineer.



DESCRIPTION ON NEXT PAGE

The preceding plate illustrates a store front similar to plate 1, but with the 3 columns between the end posts suspended from a Franklin girder and without basement piers; by their omission the daylight from the sidewalk lights, see plate 1, is free to pass back to light towards the rear of the usual dark deep basements, besides the basement is one continuous room extending under the sidewalk out to the wall which supports the curbstone. The reader will please refer to plate 1 and the reading matter opposite it, the beam which passes through the bottom of the column of figure 3, plate 1, would be applied in this construction, extending through the bottom of the 3 columns with its ends resting on and secured to the basement piers. The beam would set back of the risers and be attached as in figure 3, plate 1.

By the general use of this improvement, and with a plentiful supply of refracting lens sidewalk lights, the usual dark and damp basements (made damp by the exclusion of daylight) would be of the past, and this convenient apartment to the street would rank of comparative value for business purposes as that of the second story, besides it is so much larger.

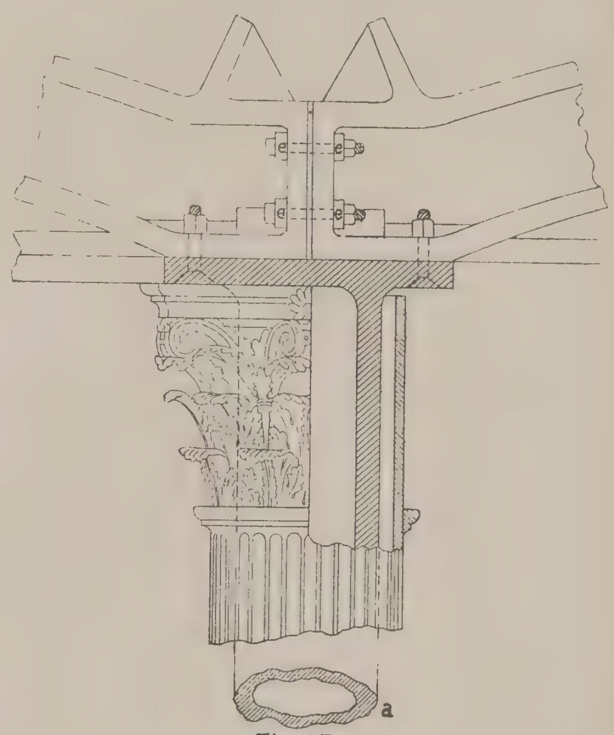


Fig.13.

The Franklin girder shown in preceding plate with the front brick wall partially built on it, is unequaled for strength in the application of the same amount of metal in any other form. The metal in the arch is employed in resisting compression, of which cast-iron has the enormous resisting strength of 93,000 pounds per square inch and wrought-iron, but about 38,000 pounds.

A summary of the peculiarities of this cast-iron arch is as follows: It is in effect a device for employing cast-iron compressively, neutralizing the tensile strain due to transverse strain. The tensile strain on the tie rods is reciprocally utilized in compressive resistance at the intrados of the arch, thus destroying the tensile strain in every part of the cross section. It has been favorably commented on by the scientific papers of the United States, London and Paris.

Figure 13 represents the ends of two Franklin girders spanning the front or rear of a double building, and bolted together, and to a fire-proof column—a substantial construction.

THE END.

PETER H. JACKSON